A Preliminary Study on Promoting the Use of Solar Energy Roof in Residential Building in Jinan

Yanwei li
School of Civil Engineering and Architecture, University of Jinan, Jinan 250022, China

Abstract. The excessive development and utilization of traditional energy makes the energy fuel (oil, coal, etc.) on the earth tend to be exhausted. At the same time, the pollutants discharged in the process of use have caused serious harm to our living environment, resulting in increasingly acute environmental problems such as climate warming and air pollution. Solar energy is inexhaustible clean energy. At present, the use of solar energy in Jinan residential buildings mainly focuses on the installation of solar water heating system in the south facade of the building, while the use of roof of residential buildings is very little. There are two ways to use solar energy on the roof of residential buildings: photovoltaic power generation and light heat conversion. Through these two ways, solar energy is converted into electric energy and thermal energy. There are many favorable factors to promote the use of solar roof in Jinan residential building. First of all, Jinan has a long sunshine time. Secondly, the usable area of Jinan residential building roof is large. In addition, the solar energy roof of Jinan residential building has a double energy-saving effect. Finally, the solar energy roof has little adverse effect on the appearance of the residential building in Jinan.

1. Introduction
With the development of social economy, people's demand for energy is increasing. The overexploitation of traditional energy makes the energy fuel (oil, coal, etc.) on the earth tend to be exhausted. At the same time, the pollutants discharged by traditional energy in the process of use have caused serious harm to our living environment, resulting in climate warming, air pollution and other environmental problems more and more acute. In the face of these problems, 175 countries around the world signed the Paris Agreement in New York on April 22, 2016, which is the second legally binding global climate agreement after the Kyoto protocol. The goal of the agreement is to reduce net greenhouse gas emissions in the second half of the 21st century, so as to control the global average temperature rise below 2 ℃ in this century. It can be seen that energy shortage and environmental pollution have become a global hot issue to be solved.

As the most active area of social and economic development, cities consume a huge amount of energy and resources. Today, more than 50% of the world's population lives in urban areas. The expansion of the population leads to the continuous increase of urban traffic capacity and the density of urban buildings, which makes more and more urban energy consumption. As a developing country, China's urban expansion speed is fast, which makes China's energy pressure more prominent. In the face of these problems, in 2017, China National Energy Administration issued the guidance on energy work, which pointed out that "we should take the structural reform of energy supply side as the main line, improve the quality and efficiency of supply, focus on recommending the development and utilization of clean energy, make up the short board of energy development, and provide strong energy security for social and economic development". It is particularly important to build a clean and
efficient modern energy system, promote the low-carbon development of the city, and promote
the sustainable and healthy development of the national economy. Therefore, the development and
utilization of less pollution and renewable new energy to make the city more energy-saving and
environmental protection is not only an important link to solve the problem of energy shortage and
environmental pollution, but also the key to ensuring the sustainable development of the city.

As a huge, clean and universal renewable energy, solar energy is inexhaustible. The advantage of
solar energy is obvious. As long as there is sunshine, solar energy resources can be developed and
utilized. Moreover, the utilization of solar energy will not cause any pollution to the environment, and
the development and utilization of solar energy products and technologies are also very mature.
Therefore, solar energy is expected to become a reliable guarantee for the construction of a
harmonious society in the 21st century. Due to the lack of open space available in the city, the existing
solar energy equipment is mainly placed in buildings, and urban buildings become one of the
important carriers of urban solar energy utilization and development. According to statistics, building
energy consumption accounts for about 32% of global energy consumption. Therefore, the
development and utilization of solar energy based on the roof of urban buildings can greatly promote
the clean production of urban buildings, reduce the consumption of urban fossil energy, and accelerate
the construction of urban ecological civilization.

2. The current situation of using solar energy on the roof of residential building in Jinan

With the development of solar energy technology and China's emphasis on solar energy utilization,
Shandong Province and Jinan City have also issued corresponding policies. On September 29, 2014, the
people's Government of Shandong Province launched 《the opinions of Shandong Province on the
implementation of GF [2013] No. 24 document to promote the healthy development of photovoltaic
industry》. According to the opinion, photovoltaic industry is an important part of new energy
industry. The development of photovoltaic industry is of great significance to the adjustment of energy
structure, the cultivation of strategic emerging industries and the promotion of ecological Shandong
construction. We will support the promotion of small-scale distributed photovoltaic power generation
systems in institutions, schools, hospitals, public institutions, residential community buildings and
structures. We will encourage the integrated application of photovoltaic buildings, and in principle,
new buildings and old buildings will be designed and constructed in accordance with the requirements
of distributed photovoltaic power generation. On December 4, 2013, Jinan issued 《the opinions of
Jinan people's Government on comprehensively promoting the development of green buildings》. According to the opinion, by the end of the 12th Five Year Plan, solar hot water system will be applied to
to all new residential buildings and public buildings with a central supply of hot water under 100m,
with an installed capacity of more than 5MW for solar photovoltaic buildings and more than 60% for
new buildings with renewable energy in cities and towns.

With the development of recent years, the utilization of solar energy in Jinan is increasing. However,
after investigation, at present, the use of solar energy in Jinan residential buildings is mainly
the use of solar water heating system. The solar hot water system of new residential buildings,
especially high-rise residential buildings, is mainly installed in the south facade of the building, as
shown in the figure 1. The use of solar energy on the roof of residential buildings is relatively small.
Some residents have installed solar water heaters on the roofs of some old buildings by themselves. In
addition, the utilization of solar energy on the roofs of most residential buildings in Jinan is in a blank
state. Therefore, there is great potential for the development of Jinan residential building roof using
solar energy.
3. The general way of using solar energy on the roof of residential buildings

At present, there are two common ways of using solar energy: photovoltaic power generation and photothermal conversion, that is, converting solar energy into electric energy or thermal energy. Therefore, there are two ways to use solar energy on the roof of residential buildings.

3.1 Solar power generation on the roof of residential buildings

The use of solar power generation is to install semiconductor materials on the roof of residential buildings, directly converting sunlight into electrical energy. At present, silicon solar panels are the most commonly used photoelectric materials for solar power generation. There are three kinds of solar power generation system: off grid power generation system, grid connected power generation system and distributed power generation system. Off grid power generation system is mainly used to provide basic living electricity for villages, pastoral areas and island farmers, herdsmen and fishermen in remote areas that are difficult to be covered by public power grid, and also can be used as emergency power supply in areas with frequent power outages. The off grid power generation system adopts the form of spontaneous self use, because of the need of energy storage battery, so the cost is high. Grid connected power generation system converts solar energy into electric energy, which is directly transmitted to the grid through grid connected inverter and grid connected switch, and then uniformly distributed by the grid to supply power to users. The construction site of grid connected power generation system is mostly suburban or remote desert, hilly and other areas with rich land resources, and the grid connected power generation system adopts the form of all power generation on grid. The distributed generation system adopts the form of self use and surplus electricity on the grid. The state and local governments have corresponding subsidy policies for the power grid. The distributed generation system can be used locally, operated flexibly, and operated independently from the grid under appropriate conditions. This system can make full use of the idle space such as roof, building surface and open space, and effectively save land resources. Therefore, the distributed generation system is more suitable for solar power generation on the roof of residential buildings.

3.2 Using solar energy to produce heat on the roof of residential buildings

The use of solar energy to generate heat is to install collectors on the roof of residential buildings to convert solar radiation into heat energy. The main solar energy utilization methods are solar collector,
solar water heater and so on. Due to the limited usable area of roof and the influence of day and night changes, solar heating can not solve the heating demand of most buildings, and the investment cost of solar heating is large, so the utilization of solar heating is limited at present. According to the design standard for energy efficiency of residential buildings (DB37 / 5026-2014) of Shandong engineering construction standard, the solar water heating system for all users in the building shall be set for the residence with 12 floors and below and the residence with more than 12 floors fwx (the effective area for which the collector can be set on the roof) ≥ AJZ (the total area for calculating the collector). The hot water produced by solar energy brings convenience to users. Therefore, the domestic solar water heater is recognized as the most mature and popular solar thermal system.[3]

4. Analysis on the favorable factors of promoting the use of solar roof in Jinan residential buildings

According to the actual situation, the promotion and use of solar roof in Jinan residential buildings has the following advantages.

4.1. Long sunshine time in Jinan

The sun is a gas star which has a continuous thermonuclear reaction in its interior and constantly and stably emits energy to space. The energy released by the sun per second is \(3.865 \times 10^{26}\) J, which is equivalent to the energy released by burning \(1.32 \times 10^{16}\) t standard coal. The amount of solar radiation energy that can reach the land surface only accounts for 10% of the total amount of solar radiation reaching the earth. However, these energies are equivalent to 35000 times of the global total energy consumption in one year.

China has a large land area, and the sunshine duration and the annual total solar radiation vary greatly in different regions. According to the amount of annual solar radiation received by meteorological monitoring stations, the country can be generally divided into four categories, as shown in the figure 2.

It can be seen from the picture that China is rich in solar energy resources, the most abundant of which is Tibet and its surrounding areas. Jinan and its surrounding areas belong to the second category of solar radiation area, and solar energy resources are relatively rich. Jinan City is located in the central part of Shandong Province. Its geographical position is between 36° 01′ - 37° 32′ N and 116° 11′ - 117° 44′ E. The annual average temperature of Jinan is about 15 °C, and the annual average sunshine hours are about 2400 hours. Therefore, Jinan is more suitable for the use of solar energy.

4.2. Large usable area of roof of residential building

Residential buildings refer to buildings for people's daily life, including residential buildings, dormitories, apartments and residential complexes. According to the overall urban planning of Jinan
(2011-2020), the residential land area of Jinan accounts for 26.6% of the total urban construction land area (excluding Laiwu district and Gangcheng District in 2019), about 109 square kilometers. If the residential building density is estimated by 20%, 5.32% of the total urban construction land area in Jinan will be covered by the roof of residential buildings, about 21.8 square kilometers. Jinan has a large roof area, which provides favorable conditions for the utilization of solar energy.

4.3. Solar roof of residential building has double energy-saving effect

Cities account for only 2% of the global land area, but the energy consumed accounts for 60% - 85% of the world's energy consumption (O'Malley, et al., 2014). At present, the development speed of urbanization in the world is still accelerating, and the urban population is expected to reach 70% of the global population by 2050 (United Nations, 2014). As the fastest growing economy in the world, China's urbanization develops more rapidly, and its urbanization rate develops rapidly. Jinan is a typical representative of China's urban development. In recent years, urban population and urban construction have increased dramatically. The promotion of solar roof in Jinan residential buildings can achieve dual functions and effectively alleviate the energy consumption of Jinan.

First of all, residential building is a special type of building, which has a large number of users and a long average daily use time. Because most of the contents of residents' daily life are completed in residential buildings, the energy consumption of residential buildings is large. According to the research, in 2015, China's total energy consumption of building operation accounted for 20% of the total energy consumption of the country, while the energy consumption of residential building operation reached 48% of the total energy consumption of the building. Jinan is a cold winter and hot summer city in the north. The energy consumption of residential buildings in the city is mainly due to the large demand for electricity and hot water in the daily life of residents. The solar roof of residential buildings can directly provide hot water system or power for residents, so it can effectively reduce the energy consumption of residential buildings in Jinan.

Secondly, the solar panel installed on the roof of the residential building can absorb the heat from the solar radiation and solve the problem of high indoor temperature of the roof in summer due to exposure. Some research shows that when the outdoor temperature exceeds 34 ℃ in summer, the indoor temperature of the top floor, the building with roof solar energy is about 2 ℃ ~ 5 ℃ lower than the building without roof solar energy, and the air conditioning load can be reduced by more than 15%. Therefore, residential buildings with solar roofs are more energy-saving and environmentally friendly than those without solar roofs.

4.4. High feasibility of installing solar energy on the roof of residential buildings

Building roof is the fifth facade of the building, which has an important impact on the beauty of the building. Compared with the traditional building roof, the solar roof has some limitations on the building shape. At present, architectural design has high requirements for the use performance and appearance of buildings, while compared with public buildings and commercial buildings in Ji'nan City, residential buildings have relatively low requirements for the appearance. At the same time, with a large number of research on the integration of solar technology and building, the adverse effect of solar roof on the appearance of residential buildings is gradually weakened. These factors are conducive to the installation of solar energy on the roof of residential buildings in Jinan.

5. Proposal

Jinan, the capital of Shandong Province, is located in the intersection of the low hills in the middle and south of Shandong Province and the alluvial plain in the northwest of Shandong Province. Jinan relies on Mount Tai in the South and crosses the Yellow River in the north. Jinan is higher in the South and lower in the north, and lower in the middle. Because of the terrain factors, the air diffusion in Jinan is slow and the pollutants are easy to accumulate. In addition, the wind speed in autumn and winter in Jinan is small, and the mixed layer height of the atmosphere is low. Because of the above comprehensive factors, Jinan often has severe pollution weather. Especially in recent years, with the
rapid development of Jinan's economy and urban scale, Jinan's urban environmental problems, especially the air pollution in Jinan, are becoming increasingly serious. The air pollution in Jinan is mainly coal smoke pollution characterized by sulfur dioxide and particulate matter. Every winter, the haze in Jinan is serious, which seriously affects the physical and mental health of Jinan citizens. The air pollution in Jinan City is mainly caused by air pollutants from fossil fuels such as coal. At present, it is transiting from coal smoke type to automobile exhaust type. In recent years, in order to improve the environmental quality, Jinan City has taken a series of measures, such as controlling coal combustion. These measures have achieved certain results. At present, Jinan has reached the critical stage of improving the urban environment. In order to cooperate with the control of coal and other measures, it is suggested that Jinan vigorously promote the use of solar roofs in residential buildings. In this way, clean energy can replace polluting energy, so as to create a more livable urban environment for citizens.

Author introduction:
Yanwei Li  Male. birth date: January, 1978. Title: Lecturer. Work units: University of Jinan. Unit location: Nanxin Zhuang West Road, Jinan City, Shandong Province, China No. 336. zip: 250022. Tel: 18678870328. E-MAIL: 29387263@qq.com.
Address: School of Civil Engineering and Architecture, University of Jinan, Jinan City, Shandong province nanxinzhuang Road No. 336, zip code: 250022

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