Solar building

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Abstract

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Abstract

In my thesis I describe the utilization of solar energy and solar energy with building integration. In introduction it is also mentioned how the solar building works, trying to make more people understand and accept the solar building.

The thesis introduces different types of solar heat collectors. I compared the difference two operation modes of solar water heating system and created examples of solar water system selection. I also introduced other solar building applications. It is convenient for the reader to know and choose what kind of solar building applications there are available.

The solar water system selection calculation is very useful for someone who wants to install a solar water system. Using solar energy applications can save much energy in daily life.

Keywords
Solar energy, Integration, Insulation, Power

Public

CONTENTS

SYMBOLS AND ABBREVIATIONS

PV photovoltaic

A_c the area of direct heat collector system, m^2

Q_p average water consumption per day, kg

C_p specific heat capacity of water, KJ/(kg·°C)

t_{end} the final temperature in the tank

t_i initial temperature

f solar guarantee rate (according to the system using period of the solar irradiation, economical system and user requirements and other factors, comprehensive consideration, should be 30%-80%)

J_T average solar irradiation per day, kJ/m^2

η_{cd} the efficiency of solar heat collector (according to the experience, general is 0.25~0.5, the specific value should be depending on the actual test result of collector products)

η_L heat lose rate of tank and piping (according to the experience, general is 0.20~0.30)

A_{IN} the area of solar heat collector of indirect system

F_RU_L the coefficient of the loss of heat collector system, W/(m^2·°C)

Flat plate solar collector, F_RU_L is better from 4 to 6 W/(m^2·°C)

The heat pipe heat collector, F_RU_L is better from 1 to 2 W/(m^2·°C)

Specific values depend on actual test results of the collector products.

U_{hx} heat transfer coefficient of heat exchanger, W/(m^2·°C)

A_{hx} the heat exchange area of heat exchanger, m^2

q_2 the design of system consumption of hot water per day

Q_w the average daily water consumption of the system

Q_d the system consumption power of heat per day

Q_h the design of heat consumption power of the system per hour

K_h hourly variation coefficient

m the number of water users

q_1 every people uses hot water per day

c specific heat capacity of water

p density of water

q_{rh} the design of hot water flow of hot water supply system per hour

V_1 volume of heat storage tank

V_2 volume of the supply heating tank

Q_3 the energy of auxiliary heating

1 INTRODUCTION

With the rapid increase of economy and technology, energy is the breath of modern society. We almost cannot do anything without energy. But now there will be less and less traditional energy resource in the earth. Therefore we need to find a new energy form and to replace the traditional based on the fossil fuels use energy forms. Solar energy is a good choice. The biggest advantage of solar energy is that this energy is renewable.

This thesis writes about comprehensive applications of solar energy and the building integration. It focuses on solar building water system, solar ventilation system, heating system and solar photovoltaic system. Because the solar water system is the most popular solar application with construction, therefore I give two examples of two different solar water systems selection. The thesis also introduces the advantages and disadvantages of solar building applications to provide more information for people to choose solar building applications.

1.1 The history of solar energy

The utilization of solar energy started from the year 1615. The first solar-powered engine in the world was invented by a French engineer - Salomon DE Cox. This solar-powered engine uses solar energy to heat the air to make expansion work and pumping machine. Between 1615 to 1900 years there were many sets of solar power plants and some other solar devices were invented in the world. Almost all of these power plants adopted the concentrated method to collect sunlight. The engines of these solar-powered plants have low power, expensive price and low practical value. Most of them were manufactured by fans of solar energy. During 20th century, the solar technology development history could be divided into 7 stages. (Zhang Heng CB50015-2003)

First stage (1900~1920): Solar energy is used in real life. In California, people built a solar-powered pumping device in 1901. (Zhang Heng CB50015-2003)

Second stage (1920~1945): Due to World War II, solar energy would not solve the energy demand from war, so solar energy research fell into the low ebb. (Zhang Heng CB50015-2003)

Third stage (1945~1965): After the end of World War II, some people noticed that oil and gas resources were being rapidly reduced. They started to appeal to promote the recovery and development of solar energy research. (Zhang Heng CB50015-2003)

Fourth stage (1965~1973): Utilization of solar energy in the growth stage. (Zhang Heng CB50015-2003)

Fifth stage (1973~1980): It is the first time when solar energy was combined with construction. In other fields it began to appear commercialized solar energy products, such as, solar water heaters, solar cell, etc. The production scale was generally slight. So the economic benefit of solar energy was not good. (Zhang Heng CB50015-2003)

Sixth stage (1980~1992): Solar energy fell into the low ebb again. The main reason was that the price of world oil greatly decreased and high prices of solar products. (Zhang Heng CB50015-2003)

Seventh stage (1992 to now): The burning of fossil fuels influenced global environment pollution and ecological damage. In this context, the United Nations held “the World Conference on Environment and Development” in Brazil in 1992. After this meeting, all countries in the world made a lot of effort to strengthen the development of clean energy technology, and solar energy was combined with environmental protection, make the solar walk out of the trough, gradually strengthened. (Zhang Heng CB50015-2003)

2 INTEGRATION OF THE SOLAR ENERGY AND BUILDING

In 21st century the human has entered the time of energy crisis. The traditional non-renewable energy sources were going to be depleted, so countries were committed to the development of new energy form. Solar energy as an inexhaustible green energy has the most development potential in 21st century, as it is one of the most clean and environment-friendly energies. Nowadays, industry is becoming more and more developed, at the same time the environment pollution has become more and more serious. Energy problem is the worldwide problem. People already realized that they cannot be completely dependent on fossil energy. In all of the energy consumption, construction and operation of buildings accounts for about 50%. Therefore, how to develop the environmental protection and energy saving building has become the issue of common concern all over the world. Undoubtedly, if we can combine solar energy with construction, it will be the best way to reduce building energy consumption.

2.1 The definition of integration of the solar energy and the building

The solar energy and the building integration are using solar energy into the overall design project, so that solar energy facilities will become the part of a building. In the future, construction will combine solar energy and aesthetic, solar energy systems convert solar energy into the required heat, electricity and other energy in the building. The solar energy and building integration not only make full use of solar energy, but also save energy and decrease pollution. The solar building for humans has economic and social significance and important energy security strategy significance. (Zhang Heng CB50015-2003)

Comprehensive consideration of social progress, technology development, economic ability and other factors in the construction planning, design, construction, use, maintenance and transformation activities, active and passive use of solar energy buildings are collectively referred to as solar building. (Zhang Heng CB50015-2003)

Solar building applications include the use function of buildings and the landlord demand of safe, convenient, comfortable and healthy environment. The technical approaches of solar building applications include the passive, active and comprehensive application. From the development of thermal insulation materials, the realization of the function of natural lighting and ventilation, solar-thermal photovoltaic technology is applied to the sunshade, light and comfortable environment. We should integrate application of solar energy resources in all aspects. Solar photovoltaic use in solar building integration will also be more broad prospects for development. (Zhang Heng CB50015-2003)

2.2 The characteristics of the solar energy and the building integration and application objects

The design idea of integration was advocated by the USA Solar Energy Association founder Steven Strand more than 20 years ago. The theme is that the semiconductor material converts solar energy into electrical energy and is directly embedded in the walls and the outer surface and roof, instead of the cumbersome installation of solar collecting device on the roof, so as to realize the integration of solar energy utilization and building. We get the electric energy from solar energy and electric energy to drive the indoor use of electric heating, indoor lighting, refrigeration equipment, etc. (Zhang Heng CB50015-2003)

2.2.1 The characteristics of the solar energy and the building integration

The application of solar energy is into the overall environment of design, the construction, technology and aesthetics, and solar facilities. It is a part of the building and the organic combination between each other, instead of traditional solar energy structure of the building influencing the image of the appearance. (Zhang Heng CB50015-2003)

The use of solar energy facilities partly or completely replaces the roof cover. It can reduce costs and improve the efficiency.

Solar energy facilities can be used for flat roof or inclined roof. Generally on the flat roof it is available the covering type and on the sloping roof - with mosaic.

2.2.2 Application of solar energy and the building integration technology applicable objects

- Solar buildings are suitable for urban construction. They are relatively strict, requiring installation specification and beautiful, do not harm the districts of the unit, the collective, community, etc. (Zhang Heng CB50015-2003)

- Solar buildings are suitable for the case when in the early architectural design the solar energy is taken into consideration as part of the building, with architectural design.

- Solar buildings are suitable for various buildings, such as residential areas, high-rise buildings, villas and so on.

- Solar buildings are suitable for new residential quarters and renovation.

2.3 The advantages of solar building

1) The solar energy technology in the buildings can effectively reduce the buildings' energy consumption.

2) After the building is combined with solar energy application, the battery panels and heat collector can be installed on the roof; it can save the land resources.

3) After combining solar energy with the building, the building can supply electric and hot water by itself, and then there does not need to be another erection of transmission line and hot water pipes. It reduces the pressure on municipal construction.

4) Solar energy products do not have noise and emission. It is renewable energy and people easily accept this kind of energy.

3 SOLAR BUILDING WATER SYSTEM

Solar water heating system and integration of residential construction is the inevitable trend in the future. If we want to solve the solar hot water system and building integration problem, we must start from the solar hot water system and synchronous it with building design.

1) Integration of the appearance (FIGURE 1): To achieve the perfect combination of solar hot water systems and building, a solar collector should be selected and placed rationally according to the characteristics of the architectural appearance, to let the solar heat collectors become one part of building. (Wang Jiawei 2009)

FIGURE 1. Integration of appearance (Tupian Solar building)

2) Integration of pipeline layout: There should be a reasonable layout for the circulating pipeline of water heating system and hot and cold water supply line. It should be possible to minimize the length of hot water piping. In building design and construction it should be pre-set aside all the piping layout and channels. (Wang Jiawei 2009)

3) Integration of building structure: When a designer plans structural design and construction of buildings, we should properly solve the problem of placement

and installation of solar collectors to ensure that the structure of the bearing, waterproof and other functions are not affected, and give full consideration of solar heat collectors' abilities of bearing, to resist wind and hail, etc. (Wang Jiawei 2009)

3.1 Operation modes of solar water heating system

- On residential roof of each household there should be installed a household solar water heater (FIGURE 2)

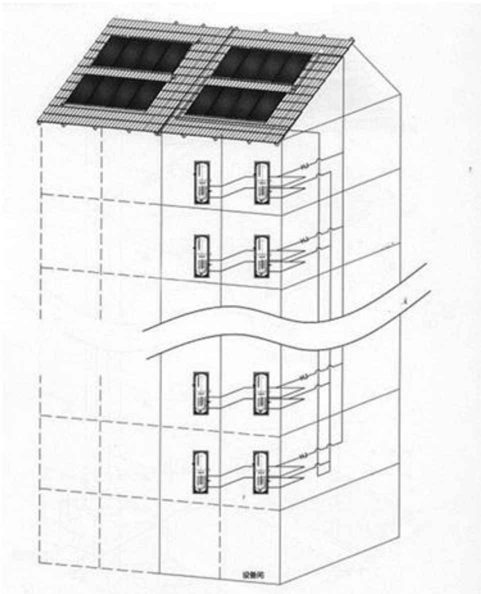


FIGURE 2. Household heat - set of household water supply (Xinglang Dichan 2013)

- A household solar water heater should be installed in the balcony of each household

- A set of Centralized water storage for solar water heating system should be installed on the roof of the building, and then through the hot water pipe supply hot water should be directed to each household (FIGURE 3). (Wang Jiawei 2009)

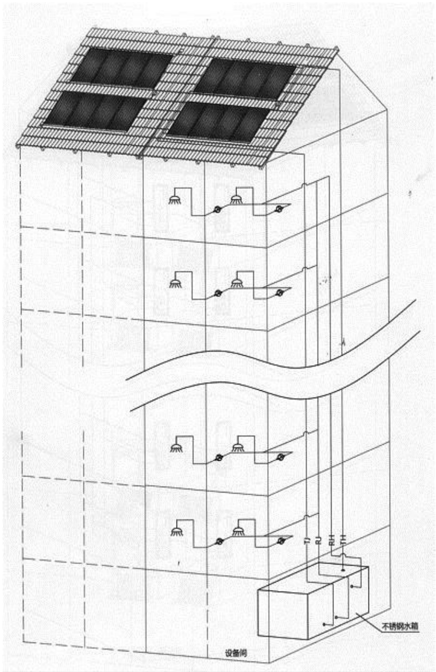


FIGURE 3. Centralized heat - centralized water supply (Xinglang Dichan 2013)

The difference between Household heat - set of household water supply system and centralized heat - centralized water supply system is following:

The maintenance of household heat - set of household water supply system is easier than centralized heat - centralized water supply system. With the household heat - set of household water supply system it is easier to control the water consumption.

Because of unified management, the outlook of centralized heat - centralized water supply system is better than household heat - set of household water supply system, and can reduce the cost of solar water system and more people can install solar water system on the roof.

3.2 Selection of types of solar heat collector

•Flat plate solar collector (FIGURE 4): High water yield, not burst pipes, can be confined, high temperature resistant, non-scaling. During use, it is economic for maintenance.

FIGURE 4. The flat plate solar collector (Visual dictionary online)

•The vacuum tube solar collector (FIGURE 5): Resists freezing, quick to start, no fouling, heat preservation is good

FIGURE 5. The vacuum tube solar collector (Evacuated tube solar collector)

•The heat pipe heat collector (FIGURE 6) and U shaped tube heat collector (FIGURE 7): Can be used in -50 °C, stable and reliable, the cost is high

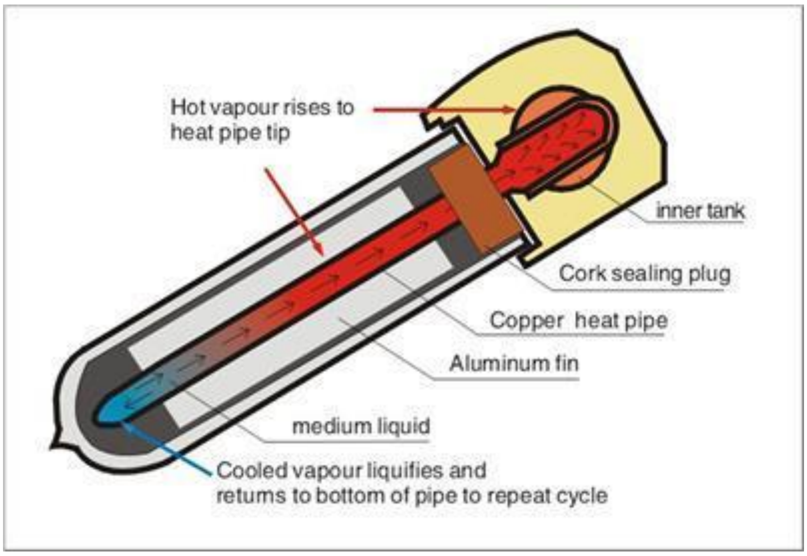


FIGURE 6. The heat pipe heat collector (Tupian Diytrade)

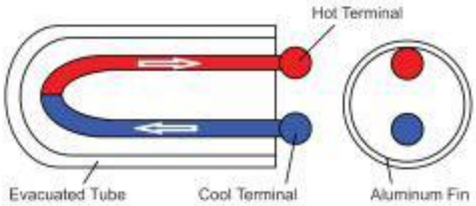


FIGURE 7. U shaped tube heat collector (Solar collector)

3.3 Area of solar energy heat collecting determination

Solar energy collecting area determination depends on the capacity of the solar water tank; the average need per 100 l water is a 1.5 ~ 2 m^2 solar collector area. If the capacity of the tank is 150~300l, then the household solar collector area should be 3~6 m^2.

The calculation method of the solar heat collector's area:

The area of the solar heat collector in a direct system: (Wang Jiawei 2009)

$$A_c=Q_pC_p(t_{end}-t_i)\ f/[J_T\eta_{cd}(1-\eta_L)] \qquad (1)$$

A_c— the area of direct heat collector system, m^2
Q_p— average water consumption per day, kg

C_p—specific heat capacity of water, KJ/(kg·°C)

t_{end}— the final temperature in the tank(<60°C)

t_i — initial temperature

f — Solar guarantee rate (according to the system using period of the solar irradiation, economical system and user requirements and other factors, comprehensive consideration, should be 30%-80%)

J_T — average solar irradiation per day, kJ/m^2

η_{cd}—the efficiency of solar heat collector (according to the experience, general is 0.25~0.5, the specific value should be depending on the actual test result of collector products)

η_L— heat lose rate of tank and piping (according to the experience, general is 0.20~0.30)

The area of solar heat collector in an indirect system: (Wang Jiawei 2009)

$$A_{IN}=A_c[1+(F_RU_L\cdot A_c)/(U_{hx}\cdot A_{hx})] \quad (2)$$

A_{IN}— the area of solar heat collector of indirect system, m^2

A_c— the area of solar heat collector of direct system, m^2

F_RU_L—the coefficient of the loss of heat collector system, W/(m^2·°C)

Flat plate solar collector, F_RU_L is better from 4 to 6 W/(m^2·°C)

The heat pipe heat collector, F_RU_L is better from 1 to 2 W/(m^2·°C)

Specific values depend on actual test results of the collector products.

U_{hx}—heat transfer coefficient of heat exchanger, W/(m^2·°C)

A_{hx}—the heat exchange area of heat exchanger, m^2

3.4 Examples: solar water system selection

First example: Centralized heat - centralized water supply system collector selection can be find in APPENDIX 1

Second example: Household heat - set of household water supply system collector selection can be find in APPENDIX 2

4 SOLAR VENTILATION AND HEATING SYSTEM

In many kinds of applications of solar building, we rarely heard about the solar ventilation system. Generally speaking, the building energy consumption accounts for 35.3% ~ 40% of total energy consumption, and has been shown increasing trend. Most of them are used for the building heating and the heating system. Therefore, the use of renewable energy becomes particularly important. But solar energy is intermittent and variable. If it can achieve all day heating or cooling hours, the efficiency would be higher. Therefore we can store the heat energy to adapt to the change of solar energy. Then we can effectively reduce energy demand and energy supply. (Niu Zhi Li peng 2010)

4.1 Solar energy air conditioner

The solar energy air conditioning combines the solar system with a refrigeration system. We use solar energy to produce the heat to drive the refrigerating machine. Or we also can use a solar energy to produce electricity to drive air-condition.

Solar refrigeration systems have adsorption, absorption, desiccant air conditioning and jet refrigeration four kinds of categories. The most widely used are adsorption, absorption and desiccant. The working principle of work of them is that they use solar collector to produce heat energy to drive a refrigerating system.

4.2 Natural Ventilation system

Natural ventilation is passive ventilation. The principle of natural ventilation is to use outside differences of pressure and air movement to cool and ventilate a building. (Niu Zhi Li peng 2010)

Natural ventilation is very important, because a natural ventilation system can provide fresh air without fans. If the climate is hot, a natural ventilation system can help to cool building without air conditioning systems. It can reduce the energy consumption of a building.

If one natural ventilation system has enough fresh air for internal space and satisfied thermal comfort, it means this natural ventilation system is successful.

4.2.1 Wind Ventilation

Wind ventilation is one kind of passive ventilation. The principle of wind ventilation is to use the wind force to pull the fresh air through the construction. Wind ventilation system is the simplest, most common and cheapest passive ventilation and cooling system. (Niu Zhi Li peng 2010)

4.3 Solar heating system

Solar heating system refers to the solar energy as a heat source heating system. The use of solar energy collector is to convert solar energy into heat energy, and to supply buildings heating in the winter and the other thermal system. Solar energy heating mode can be divided into active heating and passive heating.

Passive solar heating in buildings can be a fully solar heating collection, storage and distribution through the reasonable arrangement of the building orientation, the surrounding environment, internal space and external form. The building materials and the structure are also very important factors for passive solar heating. (Niu Zhi Li peng 2010)

Active solar heating system is mainly composed of a solar heat collecting system, storage system and heating system, automatic control systems and other energy auxiliary heating equipment and a heat exchange equipment set. Active solar heating system compared to the passive solar heating has the characteristics of high heat conversion efficiency, good heat insulation effect and internal temperature stability. However the disadvantages of active solar heating system are that one-time investment cost is higher than passive solar heating system and that the energy consumption is higher than passive solar heating system. (Niu Zhi Li peng 2010)

4.3.1 Direct solar gain

Direct solar gain is the heat from sun. We can put dark materials on the top of the building and then use building to collect heat and this heat can be retained by construction. (Niu Zhi Li peng 2010)

As direct solar gain heating is the cheapest and most common way of heating building, so it is important for any buildings that need heating. On the other hand, it is also very big problem in hot climates; we need to avoid direct solar gain.

4.3.2 Trombe wall

Trombe walls are indirect solar heat gain systems. They are thermal storage walls. A typical Trombe wall consists of a twenty to forty centimeter thick masonry wall painted with a heat-absorbing color and faced with a single or double layer of glass. The glass will be placed in front of the masonry wall 2-15 cm to create a small airspace. Dark surface will absorb heat from the sunlight passing through the glass. And then the dark surface will store heat in the wall, and heat will be conducted slowly through the masonry. (Niu Zhi Li peng 2010)

The glass prevents radiant heat escape from the warm surface of the storage wall. The wall is in the air gap. It can keep warm and heat on the wall surface further. For a forty centimeter thick Trombe wall, the heat will spend about eight to ten hours to reach the interior of the building. So, even several hours after the sunset, the Trombe wall will heat the house. This kind of a design can be used in bedrooms and residential living areas. (Niu Zhi Li peng 2010)

Furthermore, we can also install Trombe wall to heat the air within the internal space (FIGURE 9). We can open one lower and one upper air vent in the wall. It allows the convection of currents. The cooler air from the room enters into Trombe wall at lower air vent, then the heated air in the Trombe wall escapes into the room from upper air vent. These air vents must be operable, because we need to prevent the reverse of convention currents occurring in the evening. The operable air vents can also prevent over heating internal space. (Niu Zhi Li peng 2010)

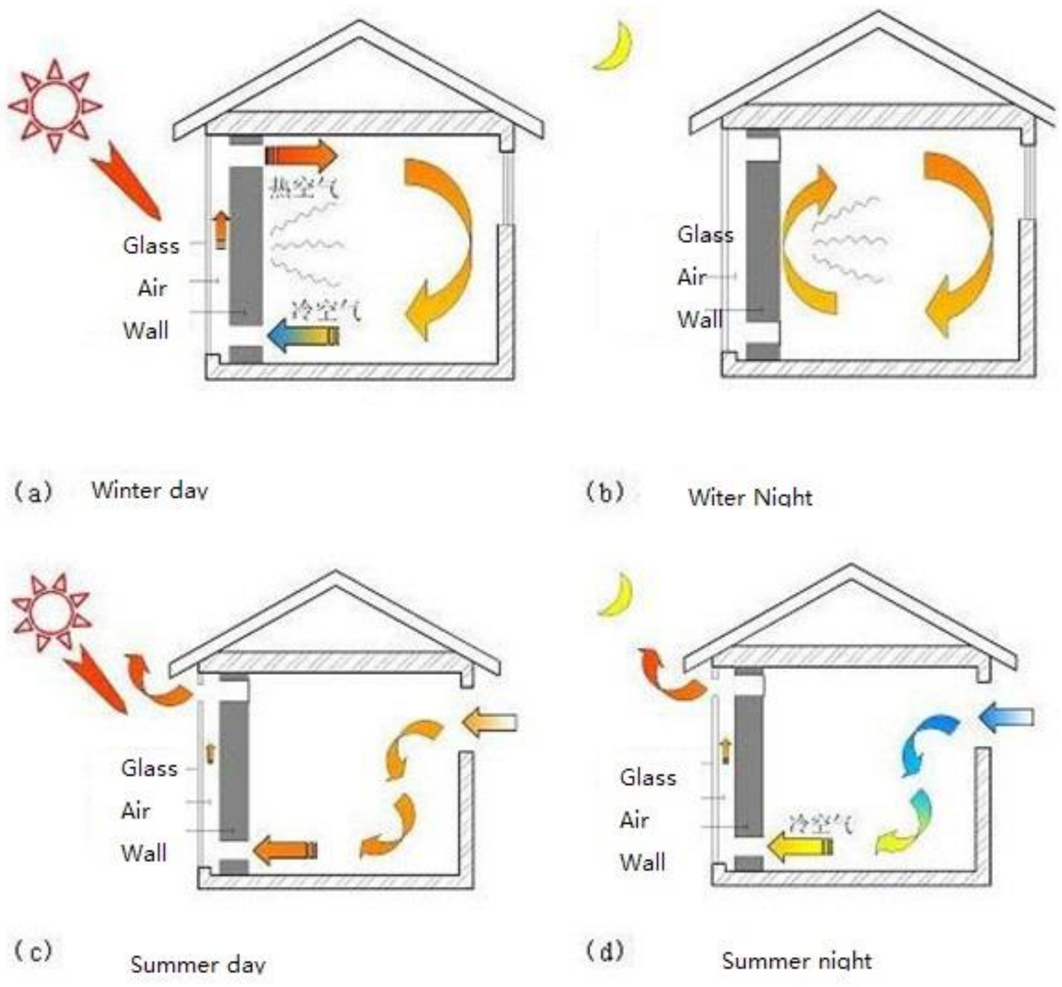


FIGURE 9. Trombe wall heating and cooling internal space in different time (Luxin Zhang)

4.3.3 Radiant heating

Radiant heating system is different with typical air condition systems, because it heats surfaces rather than air. It warms surfaces and then radiates the heat to people who live in the building. When people touch the surfaces they also can feel warm. The radiant heating system also can warm the air by convection.

FIGURE 10. A traditional radiator (Tupian Baidu)

The radiant system can sharply reduce the energy consumption of a building. On the other hand, the radiant system also provides better living condition. The traditional radiant heating systems use independent radiators (see FIGURE 10), but now the new radiant heating systems are usually built into ceilings or floor (FIGURE 11). (Mao Jian, Tang weijun 2010)

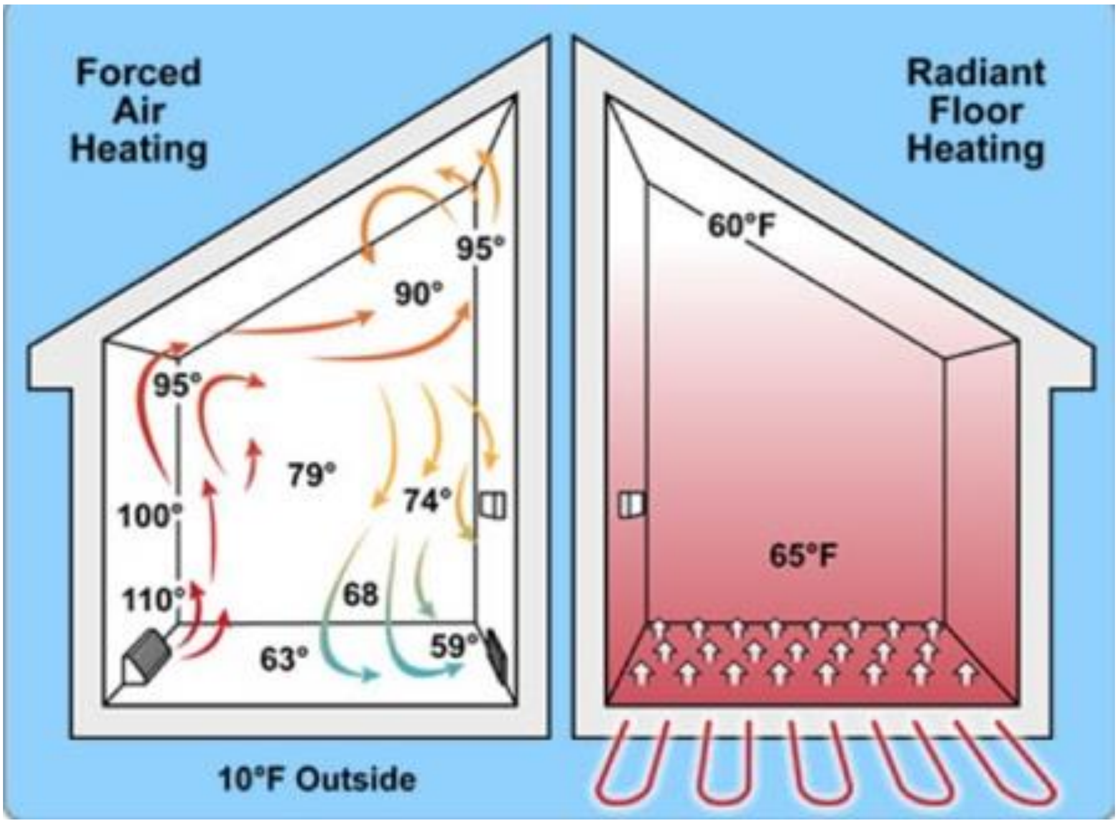


FIGURE 11. Radiant floor vs. forced-air heating debate (Michael Franco)

5 SOLAR PHOTOVOLTAIC SYSTEM

Solar photovoltaic technology means the use of solar cells to change solar energy to electric energy. This energy will be stored by the battery and in the evening the battery will supply indoor lighting and other applications.

Solar photoelectric conversion system consists of solar cells, charge and discharge controller, batteries and load. Among them, solar cells change solar energy to electric energy. The charge and discharge controller are used to control the charge and discharge of batteries. The main function of storage batteries is to stockpile the electric energy after solar cells changed solar energy to electric energy. When the user needs electricity, storage battery will provide electricity. (Niu Zhi Li peng 2010)

5.1 The advantages of PV power generation

After 1970s, because the influence of the second oil crises, PV power generation becomes very important in the world and PV power generation is developing very fast. From long-term perspective, PV power generation will enter into the electric power market, and partly instead of conventional sources of energy. The PV power generation has great significance for the environmental protection and energy strategy. The advantages of PV power generation are embodied in the following aspects: (Mao Jian, Tang weijun 2010)

- Clean
- Safety
- Extensive
- Longer life and free maintenance
- The adequacy of resources and potential of the economy

5.2 Limitations of PV power generation

Everything always has two sides. There are too many articles to introduce the advantages of the PV power generation. But it is also necessary to introduce some limitations of the PV power generation. Solar energy has low energy density and effect by seasonal variation and geographic distribution. The disadvantages of PVpower generation are embodied in the following aspects:

- The limitation of time-period: If we want PV power generation equipment to work normally to generate electricity, one of the most important conditions is sun. But the day and night cycle makes PV power generation equipment to work not constantly. It became a very big negative problem. In order to cope with this situation, the grid had to be equipped with corresponding capacity of a generator in the standby state.

- The limitation of geographical conditions: Solar photovoltaic power generation equipment is mostly installed on the top of the building or around building. If we install solar photovoltaic power generation equipment without construction then it will greatly increase the cost and damage the environment.

- The limitation of meteorological conditions: Climate impacts on photovoltaic generation. City's air quality such as air pollution, or variation such as fog or cloudy day, will make output of photovoltaic power generation drop.

- The limitation of transmission capacity: The cost of transmission is extremely high.

- The conversion efficiency of photovoltaic energy is low: PV energy conversion efficiency compared with traditional conversion efficiency energy sources (fossil energy, petroleum, hydropower, nuclear energy, etc.) is unsatisfactory.

6 CONCLUSION

This thesis involved my own knowledge about solar building applications into the work. I introduced different types of solar heat collectors. I compared the difference of two of operation modes of solar water heating system and created examples of solar water system selection. The solar water system selection calculation is very useful for someone who wants to install a solar water system. I also introduced other solar building applications. It is convenient for reader to know and based on that choose what kind of solar building applications they like. Solar building applications can save much energy in daily life. We should promote and use solar building applications.

In the modern society, an increasing number of people are concerned about the comfortable building environment; it results in the rising of building heating and air condition energy consumption. In some developed countries, the building consumption accounts for 30%~40% of the total energy consumption, the building consumption restricts the development of economy.

With the development of “the low carbon economy”, clean energy has attracted the attention of the governments. There is a sharp increase in the development of solar building in the world. It is showed in the study of solar building, design optimization of solar building and internal products and development business operation of estate. In solar building field, the USA is in a leading position in the world, and in domestic has formed a complete system of solar building industrialization. In addition, Japan, France, Germany, Australia and UK also have advanced technology of solar building applications. It is worth to mentioning that the developed countries have made “zero energy house”. That is houses works entirely by solar energy to provide all the energy consumption of the building. It represents the development trend of solar building in the 21st century.

REFERENCES

Wang Jiawei 2009 < Application of the technology of solar hot water system and the perfect combination of high-rise residential> Heilongjiang science and technology information.

Zhang Heng CB50015-2003 <Standard of building's Water Supply-drainage Design >

Kang Longping 2010<solar thermal utilization of high rise buildings> The green building.

Niu Zhi Li peng 2010 <The development of solar buildings in China and the status of solar energy and building integration> China Science and Technology Expo.

Mao Jian, Tang weijun 2010 <Research on integrated application of solar energy and building> value engineering

Internet Sources

Tupian Solar building [reference made 22.04.2014]. Available from: http://www.sd-solar.com.cn/hyzx/2950.htm

Xinglang Dichan 2013 [reference made 03.05.2014]. Available from: http://news.dichan.sina.com.cn/2013/04/07/691815.html

Visual dictionary online [reference made 17.05.2014]. Available from: http://visual.merriam-webster.com/energy/solar-energy/flat-plate-solar-collector_2.php

Evacuated tube solar collector [reference made 17.05.2014]. Available from: http://greenterrafirma.com/evacuated_tube_collector.html

Tupian Diytrade [reference made 17.05.2014]. Available from: http://www.diytrade.com/china/pd/4946604/heat_pipe_solar_collector.html

Solar collector [reference made 17.05.2014]. Available from: http://www.heating-solutions.biz/solar-heating/how-solar-heating-works.html

Tupian baidu [reference made 17.09.2014]. Available from:
http://www.kefulai.com/shehui/409952.html

Michael Franco [reference made 11.10.2014]. Available from:
http://www.bobvila.com/articles/radiant-floorvs-forced-air-heating/#.VD1XMYGSw2A

Fulu Biao [reference made 17.11.2014]. Available from:
http://imgsrc.baidu.com/forum/w%3D580%3B/sign=4e556f580fd79123e0e0947c9d0f5882/9c16fdfaaf51f3de305a863497eef01f3b2979f1.jpg

APPENDIX 1

First example:

One construction has seven floors in Zhengzhou, China, the roof is a flat roof, it has three units with 36 households. The centralized water supply system and the direct water supply system of solar water heater is arranged separately in each unit, of 4 hours hot water supply. The solar collector is installed on the roof with two water tanks. A heat storage water tank and one heating water tank are arranged separately. The heat which is collected by heat collecting system through heat exchange pipes in thermal storage water tank transfers to domestic water piping. The auxiliary heat source is arranged in heating water tank electric heater.

1) Calculation of hot water system load

(1) The number of water user

There are 12 households per unit, an average of 3.5 people per household. Totally there are 42 people using water in one unit.

(2) Calculation of system consumption of heat and hot water per day

If every people use 80 litters hot water per day q_1=80L/(people·day);

Specific heat capacity of water: c=4187J/(Kg·°C);

Density of water: p=1kg/L;

The initial temperature of water: t_L=10°C;

The final temperature of water: t_2=60°C;

The number of water user: m=42

The design of system consumption of hot water per day:

$$q_2=q_1\cdot m \qquad (3)$$
$$=80L\cdot 42=3360L/d=3.36m^3/d$$

The average daily water consumption of the system is 50% of the design of consumption of hot water system per day

$$Q_w=q_2 50\% \qquad (4)$$
$$=3.36m^3/d\cdot 50\%=1680L/d$$

The system consumption power of heat per day:

$$Q_d=mq_1c(t_2-t_L)p/86400 \quad (5)$$
$$=42*80*4187*(60-10)*1/86400=8141\ W$$

The number of water users: m=42;

Every people use 80 litters hot water per day q_1=80L/(people·day);

Specific heat capacity of water: c=4187J/(Kg·°C);

The initial temperature of water: t_L=10°C;

The final temperature of water: t_2=60°C;

Density of water: p=1kg/L;

One day 24h=86400s;

(3) The design of heat consumption power of the system per hour

$$Q_h=K_h[mq_1c(t_2-t_L)p/86400] \quad (6)$$
$$=4.8*[42*80*4187*(60-10)*1/86400]= 39079\ W$$

Hourly variation coefficient: K_h=4.8

The number of water users: m=42;

Every people uses 80 litters hot water per day q_1=80L/(people·day);

Specific heat capacity of water: c=4187J/(Kg·°C);

The initial temperature of water: t_L=10°C;

The final temperature of water: t_2=60°C;

Density of water: p=1kg/L;

One day 24h=86400s;

2) Calculation of hot water circulating flow and water supply design flow

(1)The design of hot water flow of hot water supply system per hour

Take Specific heat capacity of water c=4.187kJ/(kg·°C);

Density of water: p=1kg/L;

The initial temperature of water: t_L=10°C;

1h=3600s;

The design of heat consumption power of the system per hour: Q_h=39079 W

Hot water temperature difference of water distribution piping, take Δt=5°C, so the final temperature of water: $t_{end}=t_2-\Delta t$ =(60-5)°C=55°C;

Is added to the formula

$$q_{rh}=3600*Q_h/[c\cdot(t_{end}-t_L)\cdot p] \quad (7)$$

3600*39079/(4187*45*1)=747 L/h

3) Design of solar heat colleting system

(1) Location of solar heat collector

The solar collector is in the same direction with construction, towards to due south, angle of inclination is 31°50´ (Fulu Biao).

(2) The area of the solar heat collector

A. The area of solar heat collector of direct system

a) Determination of solar guarantee rate

The solar resource of Zhengzhou is in the middle. The solar heat collector is working all the year, so solar guarantee rate is f=0.5

b) heat lose rate of tank and piping

Because the tank and piping of the solar heat collector are in the outside of the construction, compared with inside temperature condition, outside temperature is lower, so lose rate of the tank and piping is n_L=0.25 (take this data is based on Haier company product)

c) the efficiency of solar heat collector

According to the actual test result of collector products, the efficiency of a solar heat collector, η_{cd} =49% (take this data is based on Haier company product)

The average daily water consumption of system Q_w=1680L/d;

Specific heat capacity of water c=4.187kJ/(kg·°C);

Density of water: p=1kg/L;

The initial temperature of water: t_L=10°C;

The final temperature of water: t_{end}=55°C;

Solar guarantee rate f=0.5;

Average solar irradiation per day J_T=13910kJ/m^2 (Fulu Biao);

Heat lose rate of tank and piping n_L=0.25;

The efficiency of solar heat collector η_{cd} =49%

The area of the solar heat collector of a direct system is calculated using the equation (1) and the result is 31 m^2:

$$A_c=Q_w cp(t_{end}-t_L)\ f/[J_T\eta_{cd}(1-n_L)]$$
$$=1.680*4187*1*(55-10)*0.5/[13910*0.49*(1-0.25)]= 31m^2$$

4) Solar water system selection

(1) Heat storage tank

According to 1 m^2 solar heat collector corresponding 75L heat storage tank volume, we can get volume of heat storage tank as in

$$V_1=75L\cdot A_c \quad (8)$$

$$=0.075m^3*31=2.3\ m^3$$

5) Auxiliary heat source

(1) Heating water tank

An auxiliary heat source is an electric heater in the tank; the heat water storage tank should ensure every household use 90 min of the design of heat consumption of the system per day

So, the volume of the supply heating tank is: V_2=1120 L

The design of hot water flow of a hot water supply system per hour q_{rh}=747L/h

$$V_2=90min\cdot(q_{rh}/60s/min) \quad (9)$$
$$90*(747/60) =1120\ L$$

Calculation of the energy of auxiliary heating:

Q_3= c*V_2*[(t_2-t_1)p] (10)

= 4187*1120*[(55-10)*1] = 211MJ =58.6 kw·h

The design of heat consumption of system per hour

Q_h=39079W;

Specific heat capacity of water c=4187J/(kg·°C);

Volume of supply heating tank V_2=1120L

Density of water: p=1kg/L;

The initial temperature of water: t_L=10°C;

The final temperature of water: t_2=55°C.

The description of the model of products

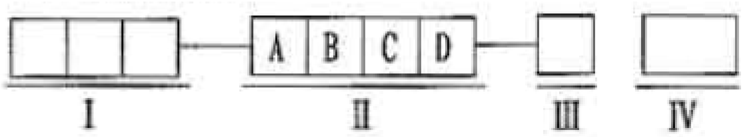


FIGURE 8. The model of product (Zhang heng CB50015-2003)

From Figure 8, we can see a product model that consist of four parts:

Part I shows the type of the product

Part II shows the character of the product: Part A shows the number of a vacuum tube; Part B shows the material of the water tank; Part C shows the material of stent; Part D shows the size of vacuum tube, e.g. 18/ϕ58, which means diameter 58 mm and length 1800 mm.

Part III shows the angle between a vacuum tube heat collecting surface and horizontal plane.

Part IV is an electric heater part of a solar heat collection. If there is not this part, it means there is no auxiliary heat source.

This is a common way to give the model of the product introduction in the solar water system manufacturing business.

APPENDIX 2

Second Example:

A household that has a separate set of centralized and the direct water supply system of solar water heater, and 24 hours hot water supply. Solar collector is installed on the roof with two water tanks. A heat storage water tank and one heating water tank are arranged separately. The heat which is collected by heat collecting system through heat exchange pipes in thermal storage water tank transfers to domestic water piping. The auxiliary heat source is arranged in heating water tank by an electric heater.

1) Calculation of hot water system load

(1) The number of water user

In this household it is 4 people.

(2) Calculation of system consumption of heat and hot water per day

Let's assume that every people use 80 litters hot water per day q_1=80L/(people·day);

Specific heat capacity of water: c=4187J/(Kg·°C);

Density of water: p=1kg/L;

The initial temperature of water: t_L=10°C;

The final temperature of water: t_2=60°C;

The number of water users: m=4

The design of system consumption of hot water per day is calculated using the equation 3 and the result is:

$$q_2=q_1\cdot m=80L\cdot 4=320L/d$$

The average daily water consumption of system is 50% of the design of consumption of hot water system per day

$$Q_w=q_2 50\%=3.2m^3/d\cdot 50\%=160L/d$$

The system consumption power of heat per day is calculated using the equation 5 and the result is 774 W.

$Q_d=mq_1c(t_2-t_1)p/86400=774W$

2) The design of heat consumption power of system per hour is calculated using the equation 6 and the result is 3970 W:

$Q_h=K_h\ [mq_1c(t_2-t_L)p/86400]$
$=5.12*[4*80*4187*(60-10)*1/86400]=3970W$

Hourly variation coefficient: $K_h=5.12$
The number of water users: m=4;
Every people uses 80 litters hot water per day $q_1=80L/(people\cdot day)$;
Specific heat capacity of water: c=4187J/(Kg·°C);
The initial temperature of water: $t_L=10°C$;
The final temperature of water: $t_2=60°C$;
Density of water: p=1kg/L;
One day 24h=86400s;

3) Calculation of hot water circulating flow and water supply design flow

(1) The design of hot water flow of hot water supply system per hour is calculated using the equation 7 and the result is 76 L/h:

Specific heat capacity of water c=4.187kJ/(kg·°C);
Density of water: p=1kg/L;
The initial temperature of water: $t_L=10°C$;
1h=3600s;
The design of heat consumption power of system per hour: $Q_h=3970W$;
Hot water temperature difference of water distribution piping, take $\Delta t=5°C$, so the final temperature of water is: $t_{end}=t_2-\Delta t=(60-5)°C=55°C$;

It is added to a formula

$q_{rh}=3600*Q_h/[c\cdot(t_{end}-t_L)\cdot p]$
3600*3970/(4187*45*1)=76 L/h

4) Design of a solar heat colleting system

(1) Location of solar heat collector

Solar collector is in the same direction with construction, towards to due south, angle of inclination is 31°50´ (Fulu Biao).

(2) The area of solar heat collector

B. The area of solar heat collector of direct system

d) Determination of solar guarantee rate

The solar resource of Zhengzhou is in the middle, so the solar heat collector is working all the year. Solar guarantee rate is f=0.5

e) heat lose rate of tank and piping

Because tank and piping of solar heat collector are in the outside of the construction, it is compared with inside temperature condition. Outside temperature is lower, so take lose rate of tank and piping is n_L=0.25 (take this data is based on Haier company product)

f) the efficiency of solar heat collector

According to the actual test result of the collector products, the efficiency of a solar heat collector is η_{cd} =49% (take this data is based on Haier company product)

The average daily water consumption of system Q_w=160L/d;
Specific heat capacity of water c=4.187kJ/(kg·°C);
Density of water: p=1kg/L;
The initial temperature of water: t_L=10°C;
The final temperature of water: t_{end}=55°C;
Solar guarantee rate f=0.5;

Average solar irradiation per day J_T=13910kJ/m^2 (Fulu Biao);

Heat lose rate of tank and piping n_L=0.25;

The efficiency of solar heat collector η_{cd} =49%

The area of solar heat collector of the direct system is calculated using the equation 1 and the result is 2.9 m^2.

$A_c = Q_w cp(t_{end}-t_L)\ f/[J_T \eta_{cd}(1-n_L)]$

$=0.16*4187*1*(55-10)*0.5/[13910*0.49*(1-0.25)]= 2.9m^2$

5) Solar water system selection

(1) Heat storage tank

According to 1 m^2 solar heat collector corresponding 75 L heat storage tank volume, we can get volume of heat storage tank that is calculated using the equation 8 and the result is 0.22 m^3.

$V_1=75L \cdot A_c=0.075m^3*2.9=0.22\ m^3$

6) Auxiliary heat source

(1) Heating water tank

An auxiliary heat source is electric heater in the heating tank; the heat water storage tank should ensure household use 90min of the design of heat consumption of system per day

So, the volume of supply heating tank is calculated using the equation 9 and the result is 114 L:

The design of hot water flow of hot water supply system per hour q_{rh}=76L/h

$V_2=90min \cdot (q_{rh}/60s/min)$
$=90*(76/60) =114\ L$

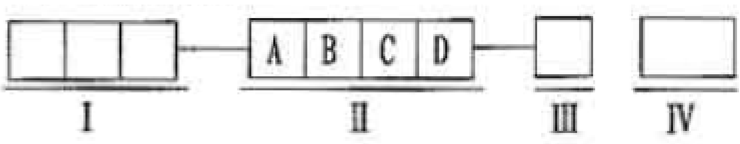
The calculation of energy of auxiliary heating is calculated using the equation 10 and the result is 5.9 kw·h.

$Q_3= c*V_2*[(t_2-t_1)p]$

$=\ \ 4187*114*[(55-10)*1] = 21.5MJ =5.9\ kw \cdot h$

The design of the consumption power of the system per hour is
Q_h=3970W;
Specific heat capacity of water c=4187J/(kg·°C);
Volume of supply heating tank V_2=114L
Density of water: p=1kg/L;
The initial temperature of water: t_L=10°C;
The final temperature of water: t_2=55°C.

The description of the model of products



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Part IV is an electric heater part of a solar heat collection. If there is not this part, it means there is no auxiliary heat source.

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