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Optimization of Energy Consumption Using Solar Bath in the Hot and Dry Climate of Iran

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Abstract

Applying modern technologies to make use of solar energy as a useful and safe resource of energy to supply hot water in public baths in hot and dry regions of Iran, due to the continental potentials they have, is one of the most useful and economical ways of using renewable energy in today's world and thus, in Iran, industry experts are investing heavily in this area. Therefore, this paper, using documentary research and field survey, seeks to make a detailed study on Iranian baths and match them with the modern technology and the indigenous culture of the area. And results indicate that, one can invest in a better future by making use of solar energy for water heating in public baths, in order to preserve and optimize energy consumption, with regard to the climate of hot and dry areas of Iran and the amount of solar radiation.

Keywords: solar energy, hot and dry climate of Iran, solar bath, optimized energy consumption

Introduction

After oil price rising in 1973, industrially developed countries were forced to reconsider the energy problem, and this was enhanced after the second oil price rising followed by the Islamic Revolution of Iran. The problem was called energy crisis or combustion crisis and paved the way for research in the field of saving or optimizing energy consumption. Industrialized countries have concluded that optimized energy consumption in industry and buildings can reduce energy consumption by 30 to 40 percent. In surveys conducted by the World Bank in 1983, it has been stated that if developing countries had energy consumption optimization typical policies, they could save an equivalent amount of 4 million barrels of oil per day, about 15% of their commercial energy.

Due to reduced fossil fuel resources and environmental pollution caused by this sort of energy, the world's attention has been drawn to the use of natural resources of energy. In the meantime, solar energy is of great importance, and thus, Iran holds an ideal condition in having this blessed gift. In this regard, power supply is one of the world's most important economic issues, that the approach to new resources of energy has developed considerably, due to the increasing rise in fossil fuels prices and nuclear energy technical issues. Among new resources of energies, solar energy holds a special place having unique advantages. Sun as a huge resource of free and endless energy, is available in almost all parts of the world, that some of the advantages include, lack of environmental pollution and lack of need for devices with moving parts and high-temperature, low maintenance costs of solar systems, and finally, the sun will be the resource of energy that can be used to heat and cool buildings, provide the required hot water and the energy required to survive. So, by operating two systems of home solar water heaters and solar baths, the solar heating was used for hot water supply in Iran. Ministries of Energy and Petroleum have taken some actions towards the installation of solar water heaters and solar baths. Ministry of Energy installed 1041 solar water heaters until 2006and did not take any actions in 2006 and 2007. Ministry of Petroleum launched

14,930 solar water heaters and 341 solar baths, from 2001 to 2007. In 2007, 1500 solar water heaters and 53 solar baths were at exploitation phase.

The impact of science and technology on architecture that cast a deep shadow on traditional architecture in all countries with different climates is an issue smilingly has transformed the architectural structure since the nineteenth century. This transformation brings dramatic changes to mind by which the mass production has been brought for the large population that had increased suddenly, in the advent of the last century. But in this transformation or rather in the new technology, climatic differences were ignored, and a single type of architecture was introduced for all types of climates, but one of the most important principles harmonizing an architectural element with the environment is that the climate should be considered in design and regardless of the temperature impacts, solar radiation amount, wind intensity, the rainfall and etc., the building will be exposed to the loss of energy. Accounting the climatic conditions in Architecture will lead to save energy .Therefore, identifying the geographic location of an area is necessary to determine the quality and quantity of the energy received at the area of sun. Given the geographical and climatic characteristics of hot and dry areas of Iran and the available potentials of receiving solar energy for installing solar collectors on public baths in the areas, one must take effective steps to optimize fuel consumption and reduce environmental pollutants.

Solar Energy

History of Solar Energy

Like using water energy, use of solar energy has a long historical background. Many prehistoric people have taken advantage of the energy for heating homes, drying clothes and food. Solar energy is important to the extent that many civilizations built primitive observatories to locate the sun in the sky, because of their great respect for it. Some others knew the value of solar energy to the extent that they even enacted laws to use the energy. Ancient Romans were heavily dependent on solar energy for heating homes and baths, that building tall structures that blocked the solar radiation to neighbors was prohibited. The ancient Romans have not been the only people so dependent on solar energy. Ancient Anasazi cliff dwellers in the southwest of America also used their knowledge on the movement of sun in the sky to heat and cool their homes. They built their homes on the rocks towards the south. In winter, sunlight shone into their homes and rocks protected them against the cold winds of the North. In the summer, rocks cast shadows on buildings and consequently, cooled them. In Iran, the ancient Iranian traditional architecture has also indicated their special interest in the proper and effective use of solar energy at ancient times. Although solar energy and its advantages have been well-known in previous centuries, but the high initial cost of such systems on the one hand, and the cheap supply of oil and gas, on the other hand, have been the barriers to the progress of these systems. Finally, the rise in oil price in 1973 caused the industrially developed countries to reconsider the issue of energy production through other ways (other than fossil fuels).

In fact, the Solar Energy available at the Sun's core is the nuclear energy. In 25% of the inner layers of the sun, hydrogen, at a speed of about a kg per second is converted into helium. This amount is equal to a mass that is shipped by 10 million rail cars. Thus, the completion of this energy is not a concern, because the sun has enough hydrogen to continue this process up to 5 million years. This energy production has been doubled by gravitational density and the sun's core is hold at a temperature of 16 million degrees Kelvin (29 million degrees Fahrenheit). Initially, the heat is radiated from the core and then reaches the sun surface through conduction and remains at a temperature of 5800 degrees Kelvin. The first way of energy transmission from the sun surface, is

electromagnetic radiation. This kind of heat transfer is largely dependent on the surface temperature of the matter and the kind of energy.

Solar energy potential in the country and its role in the Architecture

Iran is located between 25 and 40 degrees latitude and terrestrial solar irradiance on the horizontal plane ranges between 300 and 950 calories per square centimeter per day, because the highest radiation density is about 300 W/ m^2, which is about 200 watts per square meter in Iran.

However, by comparing the solar radiant energy with fossil fuels, one can find given the extent of Iran, the total amount of solar radiation in Iran is about 10^{16}MJ, which equates to 1600 billion barrels of crude oil, that by taking this amount and the annual demand for energy in the country in the construction sector into account, a significant amount will be obtained.

In the case of residential buildings and etc., the use of radiation and temperature criteria has more obvious effect. Structural aspects leading to waste energy in our country represents the influence of building design and modern architecture in cities of Iran from models which have different climate standards from those of the country. Since the solar radiant energy has an important role in the architecture of the buildings, the climate position is neglected to provide refined information of solar radiation on the range of the country, and estimate the information in the absence of direct measurements in the series of studies and providing relevant climate thresholds can meet the needs of engineers in this field (HajSaqati, 2006).

Traditional architecture of Hot and dry areas with respect to the use of renewable energy

Cities located in the central part of Iran, are always exposed to extreme summer heat, extreme cold of winter, unusual dry air, burning dust in hot summer and cold winter winds, over the year (in general the desert regions have harsh and inconsistent climate). In the past, cities were created and formed in an organic way by the people. Hence, to overcome the inappropriate climatic conditions, they built cities in the opposite direction of the prevailing winds and in the direction of the favorable winds not to be located in front of the very hot winds of the summer and the very cold winds of the winter, as well as tracks and trails were located within residential areas as very narrow grooves opposite to the wind. Mazy covered streets and paths, led create a high difference between the temperature of the shadow and the sun, and made it possible for pedestrians to pass in hot summer. On the other hand, building gardens and farms around the cities as a green belt, prevented the heat of the sun to be reflected from dry and scorching soil of desert (Hosseinian, 2003).

Thus, in the past, inhabitants of the cities located in the hot and dry climate of Iran, were able to provide themselves with favorable environmental conditions, by using local materials from desert soil and overcoming the unfavorable climatic conditions. But at present, with the use of modern technologies, the unfavorable climatic conditions of the regions were used in a manner that minimizes the environmental hazards and leads to economy. One of these technologies is the use of long radiation of sunlight in these areas, as a step toward reducing energy consumption.

The use of renewable energy in hot and dry regions of Iran

In the hot and dry climate, having severe storms coupled with sand and much heat, especially in the summer, use of technology in harmony with nature and the environment is even more important. For example, due to extreme exposure to sunlight in the summer and cold in the winter, installing solar collectors on the south to southeast parts of the building, to use the greatest amount of energy in summer is ideal. Also, in order to avoid severe winds and damage to plates fitted, the installing direction and the slope should be carried out based on the climate of the region and the different directions of the wind in the winter.

Utilization of Solar Energy in South Khorasan

South Khorasan is one of the areas that will most benefit from the sun. Although detailed studies have not been done in this regard, but available aerology data indicate the high potential of the region in the field of solar energy. Even in large-scaled studies, this potential has been taken into account. It is well known, for example, in Samimi's study (1985). In this study, Iran has divided into four areas in terms of annual solar radiation (map 1) as follows:

Radiation zone less than 350 2 cal / cm^2 per day

Intermediate radiation zone between 350 and 390cal/ cm^2 per day

High radiation zone between 390 and 430 cal / cm^2 per day

Very high radiation zone greater than 430 cal / cm^2 per day

According to the Iran map, a considerable part of South Khorasan province is located at the very high radiation zone. For this reason, the conditions to make use of solar energy is very appropriate in this area, and it can be used to create and perform research and industrial projects in terms of cooler, water heaters and solar tap water ,etc. The use that is quite effective economically.

Nevertheless, the available data to calculate the amount of solar energy in this region due to the lack of meteorological stations, cannot be accurate, and completely scientific, but based on data available at different stations (Table 1) some of the capabilities of this area in the field of solar energy are well-demonstrated (Khodabakhshi, 2002).

Table 1. Meteorological Stations in the Study Area and Reference Stations Surrounding Areas

Height from sea level	Latitude	Longitude	Kind of station	Name of station
1293	34/1	58/10	Synoptic	**Ferdows**
1840	34/7	58/23	Climatology	**Fath Abad**
1490	32/55	58/10	Evaporation measured	**Eslam Abad**
1340	33/43	58/23	Evaporation measured	**Eresk**
1110	34/20	58/41	Synoptic	**Gonabad**
885	33/53	57/35	Evaporation measured	**Boshruyeh**
1370	34/31	58/11	Evaporation measured	**Bajestan**
1435	34/43	59/11	Synoptic	**Qaen**
1600	33/20	59/14	Climatology	**Sadeh**
1491	32/52	59/12	Synoptic	**Birjand**
1117	-	-	Synoptic	**KhurBirjand**
1482	-	-	Automatic Synoptic	**Sarayan**
1211	-	-	Synoptic	**Nehbandan**

However, among the stations, only a few stations, including Birjand, Ferdows, Ghaen had the equipment to determine the solar energy and the other stations were used only for general information and obtaining the correlation relationships.

In the study method, first the amount of energy intake of each town determined, with the use of solar water heaters and similar equipment installed for the utilization of solar energy, and then the

amounts of correlation with altitude and temperature of each zone were compared. Then, according to the available data, the correlative relationships were determined and finally, the classification of the area was conducted.

Accordingly, the range of South Khorasan province in terms of energy intake is converted into 5 main sections. So that in this division, Nehbandan and Sarayan have the highest level of energy intake followed by Sarbisheh Birjand, Ferdows and Ghaenat, respectively. Accordingly, Darmian has the lowest energy intake. As can be seen in this division and the map, the energy received by this town is lower than the neighboring towns. Besides, the location of the town, suggests that the rate of energy consumption in this sector should be much higher, this is because that, information resources in the city are low or very poor. For this reason, the available estimates could not be a reality. It is hoped that further studies and appropriate opportunities would be provided. In fact, this study has paved the way for this to be done with reliable and affordable equipment in the future. In this case, one can attempt to take a scientific and accurate advantage of solar energy in the town.

Even with this limited information, it becomes clear that the relationship between the rate of utilization of solar energy and economic development in the region is a negative relationship. In other words, areas with the highest efficiency in this regard, had the lowest levels of economic development. Therefore, with the arrival of equipment and the possibility to the use solar energy, not only more and better use of this potential capacity will happen, but also the possibility of attracting investment, increasing employment and etc. will be provided. On this basis and given the circumstances described, relevant actions to utilization of solar energy in this section must be done, as soon as possible, and after obtaining positive results, other sections should be placed on the agenda according to the received priorities (Khodabakhshi, 2002).

Investigation of power supply system for hot water and hot weather in Iranian baths

As can be seen in Fig 1, hot and cold water tanks have placed in two stories above the bathroom ceiling. However, the combustion chamber is located beneath the bath and the tanks. Combustion equipment with fuel oil includes bunker tubes, electric fans, and inch tubes. Inches, in fact, are tubes to which torch flame goes directly. The water from the cold tank enters the inch and after getting warm goes to the tank for storage and use. Water movement from the cold tank into the hot tank is done based on the difference in the height of the tanks. Adjusting the volume of water in the hot and cold tanks can be done by the person in charge of the bathroom, that the volume and temperature of water used are adjusted by opening and closing the valve between two tanks and turning on or off the torch.

Hot and cold water storage tanks which are made of concrete have so thick walls that have good quality in terms of heat transfer. So that by filling the hot water tank and not using it, the water stays warm for more than one week in the summer and at least two days in the winter and it does not need reheating.

Also in order to heat bath area, furnace oil or diesel combustion gases go out from channels 4 or 5-fold crossed the floor and walls of the bath. These channels are called cats-go. With the passage of the smoke beneath the body and into the walls and even inside the hot water tank, the bathroom's body becomes very hot and according to the type of bathroom spacing, this heat is retained in the bathroom area. Thus, in the warm atmosphere, using warm water can provide a desirable bathing even in winter.

Bathroom ceilings are made as domes even in the interior space, to be more effective in keeping heat inside. With this scheme, the energy of combustion can best be used and the energy loss can be avoided.

Figure 1. Bath View from the rural village of Gisour (Southern Khorasan province)

Solar bath

Components of a solar bath system

Solar bathroom designs that have ever been implemented are different. But in general, the equipment used in public baths to provide solar water heating includes, collector, source of water supply, electrical pumps, interior plumbing and other control and electrical equipment and the water heaters are generally divided into three types that includes:

- Flat plate collectors
-Evacuated-tube
- Concentrating

Among these, flat plate collectors, as shown in Figure 2 are more common, and are our considered collectors in this paper. These collectors consist of an insulating plate in the lower part and a protected area in front of air flow in which a dark absorber plate is located and on which one or more transparent or translucent covers exist (Kianifar, 1999).

Different types of solar water heaters

Solar water heaters are classified into two broad categories: active and passive or spontaneous. In active system, as opposed to passive system, electrical pump is used to turn the heat carrier fluid. Note that the amount of hot water produced by solar water heaters depends on factors such as the installation angle and direction of the collector, recoverable amount of solar radiation and also the quality of installation, in addition to those previously mentioned.

Passive systems that lack electrical components are divided into two categories: cumulative and thermosiphon and without requiring a circulation pump, turn the hot water through the collector, and these factors, in contrast to active systems lead to more flexibility, easier maintenance and greater longevity, but the major drawback is the low efficiency.

The cumulative passive water heater includes one or more tanks, which are located inside the insulated chamber and the mirror plate is placed facing the sun. These systems are relatively heavy and expensive and consist of a few simple components and this lowers the cost of maintenance and causes them to fail to a lesser degree. Figure 3 shows an example of cumulative solar collectorsю

Thermosiphon systems rely on the evaporation of hot water, and the dominant phenomenon is the natural convection heat transfer. When the water in the hot water heater got hot, it became lighter and moves upward. While the cool water, that is heavier, moves down and the simultaneous phenomena cause natural Circulation. In order to reach the thermosiphon phenomenon, the water supply must be installed in the upper part of the collector and due to the weight of the vessel, it is necessary to install these systems very precisely, and also appropriate measures should be done to avoid system freezing. Therefore, anti-freezing circulation solution (generally water-glycol) is used.

Active systems, as previously mentioned, have pumps and other control devices, and in contrast to passive systems have a higher cost and efficiency and also their reconstruction and development are carried out more easily, that is because of the lack of hot water resource on the side or top of the collectors. However, since electrical pump is one of the main components of these systems, pumps don't work by power outages and therefore, there will be the possibility of the system freezing. To resolve this problem, a freezing valve is install, which is accounted for securing the system against freezing in coupled with the pump and it has efficiency even during the non-operation period of the pump. In freezing weather conditions, freezing valves prevent freezing by seeping warm water around the collectors. Today, in addition to water heater, power generating solar systems that are accounted for the power supply of the circulation pump direct current (photovoltaic PV) are installed, and thus they will be independent from the overall power flow. Figure 4 shows an example of a closed-loop active system (Kianifar, 1999).

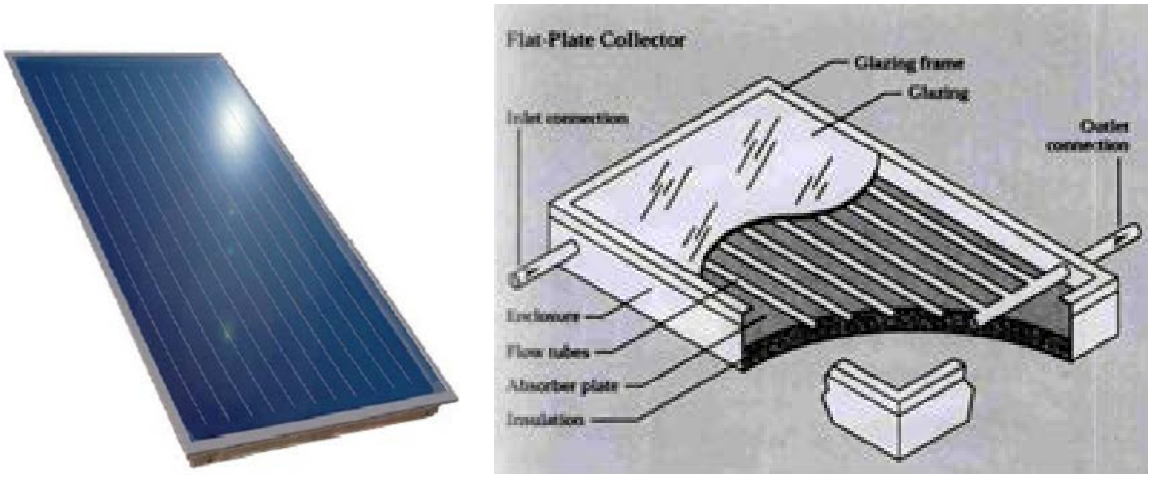

Figure 2. Flat plate collectors

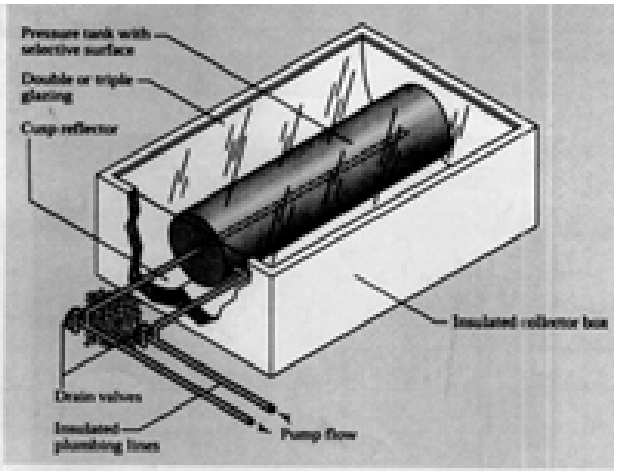

Figure 3 . Cumulative solar collector

Estimation of solar water heaters size

The most common solar energy to thermal energy is solar flat collectors. Design of solar collectors for a solar bath unit depends on light intensity, number of sunny days, the daily usage,

number of consumers, local weather, climate and customs of the people (Kreider and Kreith, 1983). Of course, providing all water consumed by solar energy throughout the year, especially with the climatic conditions of our country, is not economically reasonable (Kreider and Kreith,1999). It is expected that a solar heating scheme can provide about 60 to 80 percent of the hot water by the solar bath for villagers.

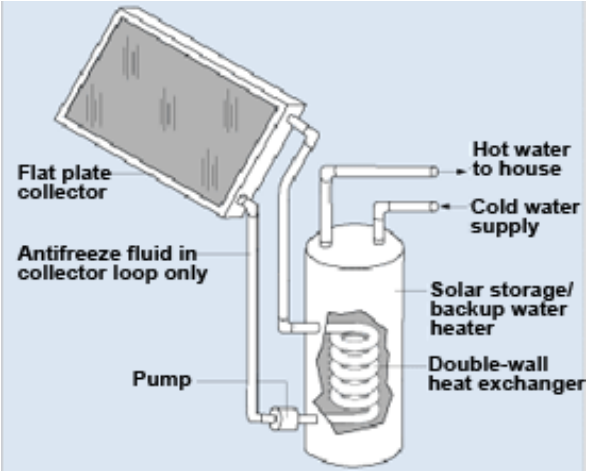

Figure 4. Closed-loop active systems

Examples of solar baths implemented in Southern Khorasan Province

The Bath of Derakhsh (in Birjand)

The solar system of the bath has also been launched by Asa Inc. The system consists of 40 collectors with an area of 2 m^2. In this bathroom, the bathroom tank is linked to a 2000-liter steel storage tank as shown in Figure 5. To transfer the heat of the collectors water content to water used, a plate heat exchanger is used. In Figure (6), a closed expansion tank is used to replace the water in collectors' cycle. In order to control the system, an electronic system has been used to establish an optimum performance between the steel tank, the concrete tank and water consumption, to control the tanks water content and pumps performance. Collectors and the steel tank are located on the ground.

Figure 5. Wall steel tanks for water storage

Figure 6. Plate heat exchanger and three circulation pumps

Figure 7. Coil of copper storage and two circulation pumps

NoghabKhor Bath (in Birjand)

The system has been run by the Sanat Gostar Sohail Inc. 60 collectors with an area of 2 square meters have been installed in this system. The characteristic of the system is that there is a slight dip in the collectors, and it creates thermo siphon water flows and as the pumps are turned off, the water circulation will be continued briefly. The storage tank of the system is a very large metal storage tank (8000 liters), which has a large coil and two powerful pumps. (Figure 7) Expansion tanks are closed-type tanks with large volume. (Figure 8) Tanks and collectors are located at the ground. (Figure 9)

Conclusion

Now, inappropriate paradigm of fuel and energy consumption in the country, particularly in the sectors of industry and services, puts pressure on the fuel and energy production and distribution networks and imposes enormous economic and social costs on the national economy, every year. Therefore, the use of new technologies such as solar energy, an endless and free resource of energy, and its great potential to reduce the environmental costs resulting from the harmful effects of fossil fuels, and more efficient use of capital investment and National resources, are to improve the standard of living and welfare. In this regard, based on Iran situation that is located in a great region of the world in terms of the energy intake, localization of the technology and its adaptation with the

climate of hot and dry regions, which have great climatic potentials, would be an effective step. Hence, according to the evaluation of solar baths implemented in Southern Khorasan (Birjand), for example, one can invest in a better future by making use of solar energy for water heating in public baths, in order to preserve and optimize energy consumption, with regard to the climate of hot and dry areas of Iran and the amount of solar radiation., , , , and the trend development in the area of solar baths construction is a step toward correcting architectural inappropriate patterns in terms of energy dissipation in society.

Figure 8. Closed expansion tanks

Figure 9. Layout of collectors

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