IJST EXPLORE International Journal of Science and Technology
CENTRE OF PROFESSIONAL RESEARCH PUBLICATIONS
ISSN 2049-7318

Journal of Science and Technology Volume 1 No. 8, August, 2012

Improved Architectural Quality of Building and its Role in Extension of Renewable Energy (A Case Study in Isfahan)

Hossein Shahinzadeh [1] , Farhad Maghzian [2] , Abbas Jahanbakhsh [3], Sayed amin Feghhi [4] , Mohammadreza Radmanesh [5]

[1] Department of Electrical Engineering, Islamic Azad University, Isfahan, Iran.
[2] Islamic Azad University, Najaf Abad Branch, Department of Art, Najaf Abad , Iran.
[3] Department of Art, Art University of Isfahan, Isfahan, Iran.
[4,5] Department of Mechanical Engineering, Isfahan University of Technology, Isfahan, Iran.

ABSTRACT

Architectural integration is a major issue in the development and spreading of solar thermal technologies. Yet the architectural quality of most existing building integrated solar thermal systems is quite poor, which often discourages potential new users. In this paper, we present of a proposal for the integration of solar thermal technology in buildings, particularized for the Iranian context through a case study, a sport complex building in Isfahan Museum Park , which consists of swimming pool, shooting, multi-dimensional cinema, computer simulator and darts. This proposal has been an action plan being implemented, which the main objective is the selection of the most appropriate technological solution for the integration of renewable energy in buildings. In this paper we propose the selection of the most appropriate technological solution for the integration of three thermal solar systems in the new building. The selection of the best solution will take into account the constructive aspects of the building, the building's energy needs and the local availability of renewable resources and market technologies. For each solar thermal system, the general scheme of the proposed technical solution is presented.

Keywords: *Architecture of Building , Renewable Energy, thermal systems, Solar buildings .*

1. INTRODUCTION

The ongoing climate changes, caused by the resource consuming life style in our modern society, put us and future generations at great risk and we are given an enormous problem to deal with. It is of the highest importance that the problem is addressed urgently and effectively. The use of fossil fuels must be signify cantly reduced and renewable energy sources must be implemented on a large scale throughout our society.

Today approximately 80% of the primary energy use in the world is provided by fossil fuels and only about 13% by renewable energy sources.

The energy use within the building and service sector accounts for a large share of the total energy use, approximately 40% in IRAN. This energy demand can be lowered signify cantly by using improved building construction techniques and a great part of the energy used for space heating and domestic hot water can be supplied by solar thermal energy, which is not only renewable, but also clean in the sense that the conversion phase does not give rise to any greenhouse gas emissions.

The solar thermal market has an immense potential for growth. The solar energy received by the earth during one hour is more than the total annual energy demand worldwide. It is obvious that we could profit from solar energy to a far greater extent than what is done today. The biggest problem has been that the cost of solar thermal systems has not been low enough to make these systems competitive on the market. This trend is starting to change with rising energy prices, but it is not changing fast enough [Anderson, T.N. and Duke, M., (2007)].

In order to widen and increase the use of solar thermal energy there are several ways to deal with the issue. Legislation is one way, already practiced in some countries. Governmental subsidies are another way, in which continuity is very important. Although the collectors of today are already highly developed it is also important to continue the development of collectors and system designs in order to improve their efficiency, quality, life expectancy, profitability etc.

A higher market growth could be achieved by the introduction of more cost-effective solar collectors. By integrating solar collectors into building elements, both building materials and the time for installation work can be saved, making the collectors more cost-effective. It can also make the collectors more attractive.

The cost-effectiveness of solar collectors can also be increased by using concentrating collectors. By replacing some of the expensive absorber by cheaper metallic reflectors to concentrate the irradiation onto the absorber, there is a potential to lower the production cost for the collectors. A reduced absorber surface also means lower heat losses [Andrews, J.W., (1981) & Bazilian, M.D., Leenders, F., (2001)].

Sun-tracking collectors with a high concentration ratio would collect the most irradiation per absorber area. However, for building integrated elements, all moving parts should be avoided. Therefore a static system with lower concentration is more suitable for building integration.

The purpose of this work is to find good design characteristics for cost-effective solar thermal systems, with the focus on the design of concentrating building-integrated solar thermal collectors.

2. CLIMATIC CHARACTERISTICS OF ISFAHAN

The Islamic Republic of Iran (I.R.IRAN) with area of about 1,648,000 km2 is located in the southwest of Asia and lies approximately between 25N and 40N in latitude and between 44E and 64E in longitude. Iran with an area of more than 1.6 million square km, Iran is the sixteenth largest country in the world (FAO, 2005). Placed in the Middle East and surrounded by the Armenia, Azerbaijan, Caspian Sea, Turkmenistan on the north, Afghanistan and Pakistan on the east, Oman sea and Persian Gulf on the south and Iraq and Turkey on the west. Population of Iran is about 70 million and the growth rate estimated as 1.7%. (FAO, 2005) and it has 30 Provinces [H. Shahinzadeh, F.Maghzian, S.A. Feghhi, O.Nematollahi, M.Radmanesh (2012)].

Isfahan is Iran's third largest city, with a population of 1.5 MM. It is located at 5,200 feet in elevation at the center of a vast desert plateau, and is famous for its impressive architecture primarily built between the 12th and 18th centuries. These traditional buildings incorporate many climate responsive building features. Isfahan was additionally selected for this report because of the extensive "rain gardens" lining the streets of the old city creating cooling green shade in a hot and arid environment.

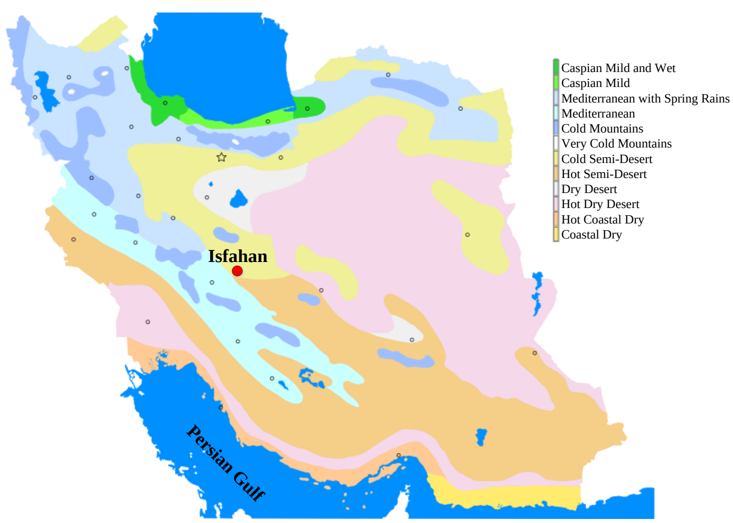

Figure 1. Simplified Climatic Map of Iran

The climate of Isfahan is semi-arid and considered temperate. It is characterized by relatively high summer temperatures, low rainfall and humidity. Winter night-time temperatures are cold.

a. *Hot Summer Temperature* – Maximum temperatures rises to 43°C, and remains relatively high at night-time even with a 21 degree fluctuation.

b. *Winter temperature below freezing* – The months of November through March have the potential to drop below freezing at night.

c. *Strong Sun* – UV index at 11 in the summer months is considered very high or extreme.

d. *Very Dry* - less than 5 inches of rain annually, principally in the winter months.

e. *Low Humidity* – Humidity ranges from a high of 60% in the winter to a low of 25% in the summer.

f. *Wind Direction and Speed* – Wind is typically westerly, ranging from 8 Km/Hr. in the winter to 22 km/hr. in the spring. Wind has been recorded up to 58 km/hr. creating dust/haze.

g. *Daylight* – Isfahan is located at 32°38’N with maximum summer daylight hours of 14 hours, and 10 hours in the winter.

h. *Earthquakes* – Iran is prone to earthquakes, and Tehran (340 KM to the north of Isfahan) sits on 100 fault lines. Isfahan is considered a moderate fault zone.

i. In summary, the climatic factors of Isfahan mean that they are not within the temperature comfort zone, swinging between being hot and dry in the summer (with strong sunlight) and relatively cold and dry in the winter.

TABLE I : Climate data for Isfahan

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Record high °C	20	23	27	32	37.6	41	43	42	39	33.2	25.5	21.2	43
Average high °C	9.2	12.5	17.0	22.7	28.2	34.3	36.7	35.6	31.8	25	17	11	23.42
Average low °C	−2.5	−0.4	4.1	9.3	13.7	18.5	21.0	19.1	14.7	8.9	3.2	−1	9.05
Record low °C	−19.4	−12.2	−6.2	−4	4.5	10	13	11	5	0	−8	−13	−19.4
Precipitation mm	19.9	14.2	21.7	18.9	8.7	1.2	1.7	0.3	0.1	3.9	12.5	19.7	122.8
% humidity	60	50	43	40	34	25	25	26	28	38	50	60	39.9
Avg. precipitation days	4.0	2.9	4.1	3.4	2.0	0.3	0.3	0.1	0.0	0.8	2.2	3.8	23.9
monthly sunshine hours	203.6	216.8	243.7	250.0	308.7	348.3	349.4	339.7	311.3	281.5	224.2	197.0	3,274.2

3. SOLAR THERMAL ENERGY

Heat captured by an active solar heating system can cover a signify can’t part of the energy demand of high-performance (h.p.) houses, i.e. buildings with very low energy demand. Because the space heating demand of such buildings is very low, the year-round energy demand for domestic hot water (DHW) becomes relatively important. An active solar system can cover a large part of this energy demand, often more than 50%, since the demand also occurs in summer. The question is whether or not to design the solar system as a combine system that also contributes to the space heating, which means that a water-based heat distribution system is required. A key issue then is estimating the space heating contribution realistically, given the shorter heating period of high performance housing.

If a water-based heating system is preferred, a solar combine system is a good option. It provides flexibility to the heating system as it is built up around a joint storage tank, serving both the DHW and space heating systems and it can be heated by both the solar collectors and auxiliary energy sources connected to the tank, depending on conditions. There are many interesting combine system designs on the market, varying by region and the locally used auxiliary energy sources. The system illustrated in Figure 2. Uses a wood pellet boiler and an electric resistance heater as auxiliary energy sources to back up the solar circuit. The tank is equipped with a device to enhance thermal stratification. The domestic hot water is heated by an external heat exchanger [Brinkworth, B.J., (2006) - Chow, T.T., He, W. and Ji, J., (2006) - Chow, T.T., He, W. and Ji, J., (2007) & Coventry, J.S., (2005)].

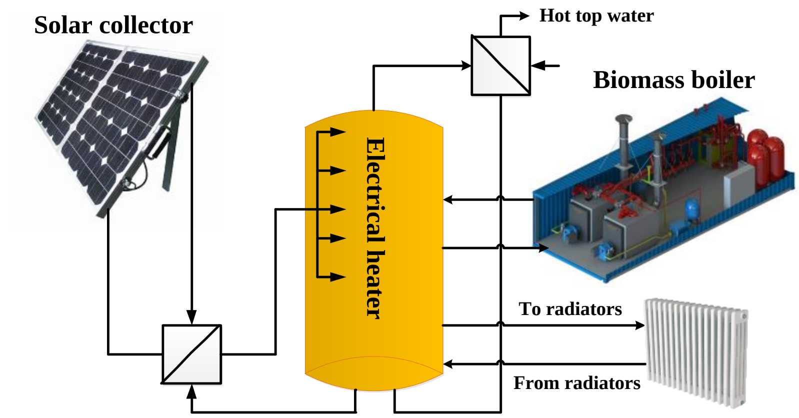

Figure 2. A solar combine system with a joint storage tank

A critical design condition for solar thermal systems is the case of minimum heat demand and maximum solar gains, as often occurs in summer. To minimize the system overheating in such instances the solar system should be designed to just cover the summer energy demand, accepting a small solar coverage in winter. An important advantage is that the combustion backup heating can be shut down during the summer. Thereby, short cycling of the backup system in summer can be eliminated, increasing the life expectancy of the system.

4. EVALUATION OF ANGLE CONCENTRATING COLLECTOR

Measurements of the transverse incidence angle dependence of a concentrating collector were performed with the collector mounted so that the absorbers are directed in the north south vertical plane, tilted so that the normal of the glazing is oriented towards south, as shown in Figures 3. and Figures 4 [De Vries, D.W., (1998) & Florschuetz, L.W., (1979)].

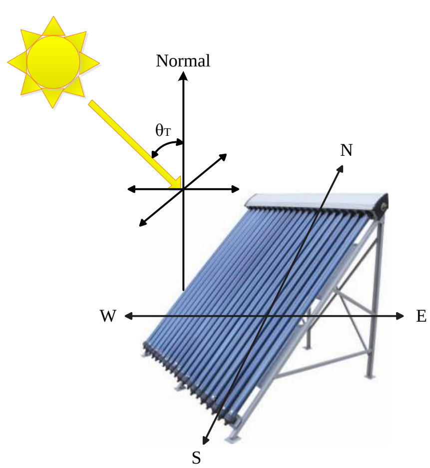

Figure 3. Measurements of the transverse incidence angle

The collector tilt was then constantly adjusted during the measurement (basically by rotation around an east-west oriented axis) so that the sun was in an east-west plane perpendicular to the front of the solar collector. This means that the incidence angle in the longitudinal plane, θ_L, is zero. Also, the incidence angle is minimized and equals the transverse incidence angle θ_T (for this collector in the east-west direction) at all times. The transverse incidence angle can therefore be calculated from Equation 1, which gives the incidence angle as a function of the declination and the time angle for a tracking surface in a plane rotated about a horizontal east-west oriented axis that is continuously adjusted to minimize the incidence angle [Garg, H.P. and Adhikari, R.S., (1999)] .

$$\cos(\theta) = (1 - \cos^2\delta \cdot \sin^2\omega)^{\frac{1}{2}} \quad (1)$$

Figure 4. A solar collector mounted on the roof and adjusted to different tilt angles

The results were verified by checking an incidence angle indicator. The calculated and measured angles showed good correspondence and this method appears to work well, which is beneficial as data from a high number of incidence angles can be collected in a short time.

5. THE CASE-STUDY OF A SPORT COMPLEX BUILDING IN ISFAHAN MUSEUM PARK

The sport public building is new and built according with the highest thermal standards. There is a very high emphasis on improving the building's low energy consumption. Taking 7.5 meters of height, the building is composed of approximately 4500 sq. meters that make up swimming pool, shooting, multi-dimensional cinema, computer simulator and darts.

It main characteristics are: south orientation of the main facade, a flat roof with an available area of 3500 sq. meters, where solar thermal collectors can be installed. Building design is presented in figure 5.

One of the main objectives of this work is to find a technical solution for the integration of three thermal solar systems. Two systems are used for heating swimming pool and the third one is dedicated to domestic hot water.

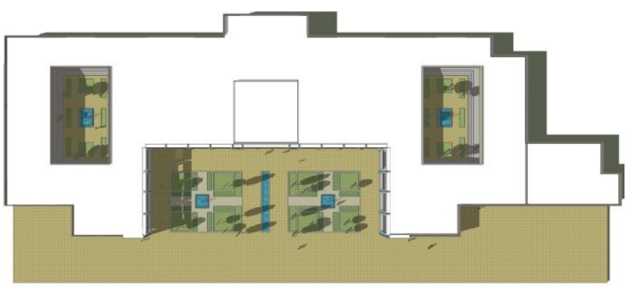

Figure 5. Building design

5.1 Solar Heating for Swimming Pool

The competition pool has an area of 312.5 m^2 and a volume of 690 m^3. The pool operation is the same every day, from 7 AM to 11 PM, except March, when the pool closes for holiday and for equipment maintenance. The number of users of the competition pool is presented in Table 2.

TABLE II: Number of users of the competition pool

Timetable	Number of users
7 - 9	20
9 - 11	30
11 - 13	25
13 - 15	20
15 - 17	35
17 - 19	35
19 - 21	40
21 - 23	20

For this pool, from the operating parameters selected: Temperature of water renewal 12 °C; Pool temperature 27 ºC; Replacement of water 4% , the following requirements were obtained : Temperature of water injection 37.5 ºC; Thermal requirements 1150 kWh/day .

According thermal requirements and considering a solar fraction of about 50%, the installation needs a collector array of 100 collectors, having a capture area of 400 sq. meters, and a 15,000 l. storage capacity of hot water.

The collector array is arranged as showed in figure 6, to ensure hydraulic balance. Collectors will be installed on the flat roof with an available area of 3500 sq. meters and with an angle around 50º [Garg, H.P. and Agarwal, R.K., (1995) & He, W., Chow, T.T., Lu, J., Pei, G., Chan, L., (2006)].

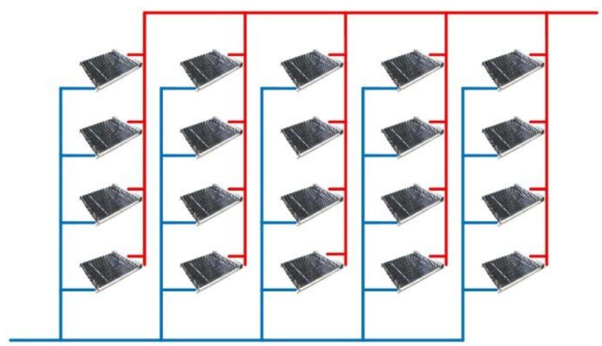

Figure 6. The collector array

As a backup of the solar energy heat source, an auxiliary heater was mounted. The general scheme of the heating system for swimming pool is presented in figure 7.

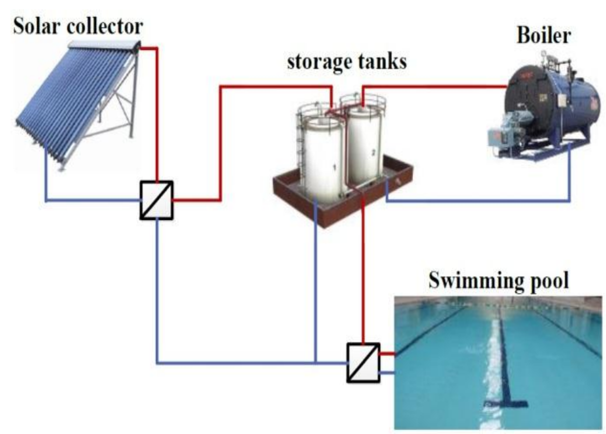

Figure 7. Scheme of the heating system for swimming pool

5.2 Solar Heating for Domestic Water

The daily hot water requirements presented in Table 3 was calculated according to the number of users and assuming a consumption of 30 litters of hot water for user. As for public services, the hot water temperature considered was 40º C [Hegazy, A.A., (2000)].

TABLE III: Hot water requirements

Timetable	Hot Water Requirements (L)
7 - 8	600
8 - 9	750
9 - 10	900
10 - 11	2200
11 - 12	2400
12 - 13	1500
13 - 14	1000
14 – 15	800
15 - 16	700
16 - 17	900
17 - 18	2000
18 - 19	2400
19 - 20	2200
20 - 21	2000
21 - 22	1000
22 - 23	600

Figure 8 is presented for integration of all the solar systems and Building design.

Figure 8. Integration of all the solar systems technologies

5.3 Economic Analysis

Costs associated with the solar thermal system for competition pool, taking into account the selected materials, are presented in Table 4. The total investment cost of the installation is 214,345.6 $.

TABLE IV: Costs of thermal solar systems

Description	Quantity	Total price
Solar thermal collector	100	126720 $
End caps	25	75.6 $
Gasket	5	274.5 $
Fixation system	25	35,490 $
Storage tank (10000 L)	2	27,144 $
Stratified charging module	1	13,117.5 $
Connection pipe and accessories	1	3,750 $
Antifreeze	1	1,602 $
Flow volume meter	5	1,302 $
Three-way motor valve	2	259 $
Expansion tank (500 L)	1	1,200 $
Expansion tank (1000 L)	1	2,700 $
Circuit control unit	1	711 $
TOTAL		**214,345.6 $**

The economic analysis, presented in Table 5, of the thermal solar systems considered in the study.

TABLE V: Economic analysis of the thermal solar systems

	Sport complex building
Initial costs ($)	214,345.6 $
Avoided energy costs ($)	795954 $
Reinvestment ($)	278049 $
Maintenance ($)	53353 $
Recovery ($)	2676 $
Balance ($)	802695 $
Simple pay back (years)	10 years
Net Present Value ($)	324912 $
Internal Rate of Return (%)	6.9 %

As we can see from Table 5, all the systems present economical benefits during the 10 years of its life time. If the national/governmental subsidies available for solar thermal systems in public services were considered in the benefit analysis, the results would be much more attractive.

6. CONCLUSION

Over the course of this study a number of the design parameters associated with the development of building integrated photovoltaic/thermal solar collector have been examined. In addition, by integrating electricity generation, water heating and facade elements it is possible to reduce the complexity associated with traditional solar installations while also achieving an architecturally sensitive appearance. As such the building integrated photovoltaic/thermal is ideally suited to environments where facade space with suitable solar access is limited, or where large numbers of people share a single building.

In this paper we have a proposal for the integration of thermal solar systems in a sport complex building in Isfahan Museum Park. The main objective of this work was the selection of the most appropriate technological solution for the integration of renewable energy in this specific building. In the Last part, the benefit of doing this has been shown. It was found that solar thermal technologies can be a sustainable option, economically viable, financially rewarding and environmentally friendly, namely for domestic hot water systems and for applications with high thermal requirements, with a simple pay back of 10 years, and with an internal rate of return of 6.9%, respectively.

REFERENCES

[1] Anderson, T.N. and Duke, M., (2007), Analysis of a Photovoltaic/Thermal Solar Collector for Building Integration, *Proceedings of SB07, New Zealand Sustainable Building Conference,* Auckland, November 2007.

[2] Andrews, J.W., (1981), Evaluation of flat-plate photovoltaic/thermal hybrid systems for solar energy utilization, US Department of Energy, Report No. BNL-51435.

[3] Bazilian, M.D., Leenders, F., (2001), Photovoltaic cogeneration in the built environment, *Solar Energy,* Vol. 71, No.1, pp.57-69.

[4] H. Shahinzadeh , F.Maghzian , S.A. Feghhi , O.Nematollahi , M.Radmanesh , (2012) ; Reduction of Energy Consumption Through using Solar Heating and Ventilation , International Journal of Engineering Research and Applications (IJERA) , Vol. 2, Issue 3, May-Jun 2012, pp.1260-1264.

[5] Brinkworth, B.J., (2006), Optimum depth for PV cooling ducts, *Solar Energy,* Vol. 80, pp.1131-1134.

[6] Chow, T.T., He, W. and Ji, J., (2006), Hybrid photovoltaic-thermosyphon water heating system for residential application, *Solar Energy,* Vol. 80, pp.298-306.

[7] Chow, T.T., He, W. and Ji, J., (2007), An experimental study of facade-integrated photovoltaic/water-heating system, *Applied Thermal Engineering,* Vol. 27, pp. 37-45. Coventry, J.S., 2004, A solar concentrating photovoltaic/thermal collector, PhD Thesis, Australian National University.

[8] Coventry, J.S., (2005), Performance of a concentrating photovoltaic/thermal solar collector, *Solar Energy,* Vol. 78, No. 2, pp. 211-222.

[9] De Vries, D.W., (1998), Design of a photovoltaic/thermal combi-panel, PhD thesis, Eindhoven University.

[10] Florschuetz, L.W., (1979), Extension of the Hottel-Whillier model to the analysis of combined photovoltaic/thermal flat plate collectors, *Solar Energy*, Vol. 22, No. 4, pp. 361-366.

[11] Garg, H.P. and Adhikari, R.S., (1999), Performance analysis of a hybrid photovoltaic/thermal (PV/T) collector with integrated CPC troughs, *International Journal of Energy Research*, Vol. 23, No. 15, pp. 1295-1304.

[12] Garg, H.P. and Agarwal, R.K., (1995), Some aspects of a PV/T collector/forced circulation flat plate solar water heater with solar cells, *Energy Conversion and Management*, Vol. 36, No.2, pp.87-99.

[13] He, W., Chow, T.T., Lu, J., Pei, G., Chan, L., (2006), Hybrid photovoltaic and thermal solar-collector designed for natural circulation of water, *Applied Energy,* Vol. 83, pp.199-210.

[14] Hegazy, A.A., (2000), Comparative study of the performances of four photovoltaic/thermal solar air collectors, *Energy Conversion and Management,* Vol. 41, No. 8, pp. 861-881.