ZIBELINE INTERNATIONAL PUBLISHING
Print ISSN : 2377-6234
Online ISSN : 2377-8342

CODEN : ERCCBC

Energy Reviews (ER)

DOI : http://doi.org/10.26480/er.01.2018.01.04

USE OF SOLAR ENERGY FOR BUILDING AIR CONDITIONING AND DOMESTIC HOT WATER PRODUCTION – CASE STUDY ELBREGA-LIBYA

Monaem Elmnifi[1*], Moneer Alshilmany[2], Mabroka ALhammaly[3], Otman Imrayed[4]

[1]Department of Mechanical Engineering, Benghazi University, Libya
[2]Department of Electricity Engineering, Benghazi University, Libya
[3]Department of Science Environment and Engineering, Omar Al-Mukhtar University, Libya
[4]Department of Electrical & Electronics Engineering, Sirte University, Libya
[1]Presenting author: monm.hamad@yahoo.com

ARTICLE DETAILS

Article History:

Received 7 November 2017
Accepted 10 December 2017
Available online 5 January 2018

ABSTRACT

The aim of this study is the evaluation of the economic and technical viability for the installation of a solar air conditioning system based on parabolic solar concentrators and adsorption technology, in an existent building. As case study was selected a bright star university located in elbrega city- Libya. Besides air conditioning, this system is also used for domestic hot water production .This solution enables the system use throughout the year in order to maximize the investment and reducing environmental pollution resulting from the use of fossil fuels in energy production .Results show that the implementation of these systems is feasible for the Libya reality and the climatic conditions enjoyed by most Libyan cities in terms of the intensity of solar radiation and most of the land is predominantly desert.

KEYWORDS

Solar Energy, Solar Cooling, Adsorption Cooling, Parabolic Through Collector

1. BACKGROUND OF THE STUDY

Libya lies in the center of North Africa between latitudes 20 - 33 ° N and longitude 10 - 25 ° E. The country is located in the Sun Earth belt and about 88% of its territory is considered in the desert. According to the report of the Institute of Thermodynamics Engineering at the German Space Center in Stuttgart [1]. Which shows that direct natural solar radiation varies from 1900 kWh / m2 / year in the far north of the country to more than 2,800 kWh / m2 /year in parts of the south-east. Based on a study, concentrated solar power plants can be considered economically valuable only for sites with direct solar radiation above 1800 kWh / m2/ year [2]. All Libyan lands can meet this condition with higher potential than the southern parts of the country.

The sector of buildings is, on a global scale, one of the largest energy consumers (together with transport and industry sectors), becoming essential to ensure a higher energetic and environmental efficiency, thermal comfort and health conditions. Over time arose solutions to answer more directly to user's comfort needs. One solution was the widespread use of air conditioning systems based on electric driven compression technology, which have improved greatly the quality of indoor environment in buildings. However, these systems improved greatly the quality of indoor environment in buildings. According to a study, these systems immediately registered high energy consumption, heating and cooling, as well as, and nowadays represent an important share in the overall consumption of the building with comfort levels ever higher, the costs associated with air conditioning has been increasing and is expected that this growth will be even more pronounced in coming years, either due to the rising standards in comfort required by the occupants or even due to climate changes [3,4].

Based on a study, nowadays in Libya, buildings account for about 60% of the electric energy consumption and about 30% of primary energy consumption, this makes this sector a target for intervention as regard the improvement of energy efficiency ratings [5]. Thus, any measure to keep or improve standards in indoor comfort and at the same time allowing the reduction in the energetic bill should be aim of interest and study. With this in mind, this study proposes to analyze the use of a solar based system to obtain the required thermal energy for heating and cooling, as well as the production of Domestic Hot Water (DHW).

Solar cooling is a solar thermal technology that produces cold by exploiting solar energy allowing significant savings compared with traditional air conditioning plants. This is also due to the fact that the main cooling demand can be covered at the moment of maximum solar radiation. According to a researcher, solar energy is used to provide heat to a thermodynamic cycle that allows to produce cold water [6].

2.1 Parabolic Troughs

Parabolic troughs are collectors designed to reach temperatures over 100ºC and up to 450ºC (with a concentration ratio around 26) and still keeping high efficiency due to a large solar energy collecting area with a small absorber surface.

Figure 1: Parabolic trough solar collector (PTC 1200).

According to a study, smaller parabolic troughs in Figure 1, (PolyTrough 1200) standard collector module is 1.2m wide, 24m long and 1.6m high. It consists of [7]:

- 12 composite reflector panels, each 2m long by 1.2m aperture
- 5 rigid galvanized steel mounts for ground or roof mounting with flexible spacing
- A structurally efficient galvanized torque tube
- A tubular receiver with glass envelope
- An accurate solar tracking system

2.2 Adsorption Chiller

The adsorption system in Figure 2 can be compared to a conventional air conditioner or refrigerator with electric powered mechanical compressor replaced by a thermally driven adsorption compressor. The ability to be driven by heat which is used for desorption, makes adsorption cycles attractive for electrical energy savers. Also, since fixed adsorbent beds are usually employed these cycles can be operational without moving parts other than magnetic valves.

Based on the study, this results in low vibration mechanically simple high reliability and very long-life time. The uses of fixed beds also result in intermittent cycle operation, with adsorbent beds changing between adsorption and desorption stages [8, 9].

3. METHODOLOGY

To supply the energy for air conditioning and DHW was considered a system in which thermal energy is supplied through the use of Parabolic Trough Solar Collectors (PTC) combined with an adsorption system (for cold production). For this, several approaches were made in what concerns the system sizing. These approaches consisted in sizing the system taking into account the energy required to meet the building energy needs, considering: monthly average area of collectors, average area of collectors in the heating period, average area of collectors in the cooling period and month in which is needed greater area of collectors. Another aspect to consider is that the installed collector power is equal to the power needed to satisfy the energy demand of the building. It is expected that total energy needs will not always be satisfied due to the fluctuation of the available solar energy along the day.

3.1 Solar radiation

In Table 1 are presented the solar radiation parameters for ELbrega city used for this study. According to a study, these values were obtained from the atmospheric science data center maintained by NASA and refer to the project site [10].

Table 1: Solar parameters

Month	Insulation	Direct Normal Radiation
	[hours]	$[kWh/m^2]$
Jan	10	3.21
Feb	11	4.18
Mar	12	5.39
Apr	13	6.48
May	14	7.06
Jun	15	7.65
Jul	15	7.79
Aug	14	7.20
Sep	12	6.06
Oct	11	4.82
Nov	10	3.57
Dec	10	2.94

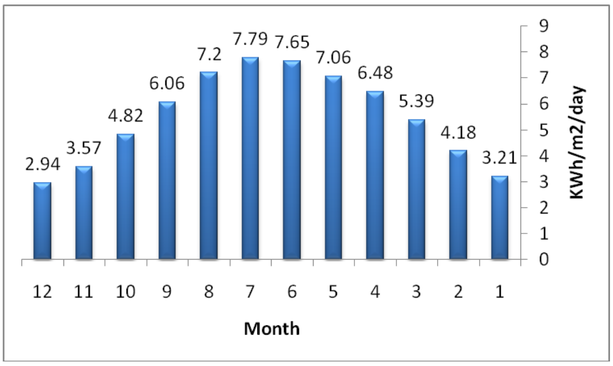

Figure 3: The average solar radiation of ELbrega city

3.2 Energy costs

The considered energy costs are presented in Table 2.

Table 2: Considered prices

Electrical Energy	0.4	D/kWh

The prices presented in the Table 2 were obtained from the energy bills of the building. All prices used in this study are reported to 2010 [5].

4. CASE STUDY

For this study was selected an administrator building of Bright Star University. The building is composed by two floors with a total surface area of 1.450 m2. The building does not have any heating system. The building is cooled using an Electrical Energy (EE). Due to the non-existence of system, it was considered that the cooling of the building is achieved by using an electrical compression chiller with a Coefficient of Performance (COP) of 3. Table 3 lists the heating and cooling periods taken into consideration for this study.

Table 3: Heating and cooling periods

Heating	From November to March
Cooling	From April to October

Figure 4: A view of building

4.1 System description

The thermal energy captured in the solar collectors is transferred to the internal circuit through a heat exchanger. The backup will be assured by the existing hot water system (liquid/liquid). For DHW storage is used a thermal reservoir that shall come into operation when the solar collectors do not provide enough energy to satisfy the building energy demand. The system will alternate between the production of heat in the winter and cold in the summer, depending on the direction of the hot water circuit. The heating and cooling of the different indoor spaces will be done through heat exchangers (water/air) mounted in the air handling units of the building. To mitigate fluctuations in the supply of cold water, as well as to

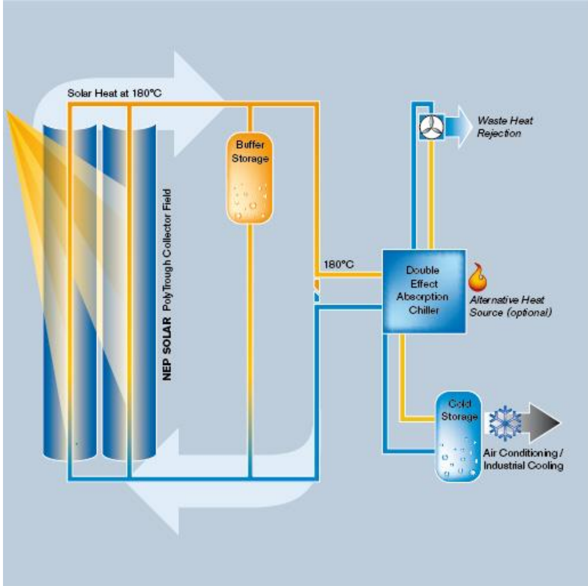

Figure 5: Operating principle diagram

4.2 Energy needs of the building

The heating and cooling needs presented in Table 4 were determined by using a Calculation equation for cooling and heating loads.

Table 4: Energy needs

Month	Heating [kWh]	Cooling [kWh]	Total [kWh]
Jan	27.300	0	27.300
Feb	16.000	0	16.000
Mar	8.000	0	8.000
Apr	0	10.240	10.240
May	0	24.194	24.194
Jun	0	27.628	27.628
Jul	0	31.104	31.104
Aug	0	33.990	33.990
Sep	0	32.760	32.760
Oct	0	28.220	28.220
Nov	12.000	0	12.000
Dec	23.400	0	23.400
Total	86.700	188.136	274.836

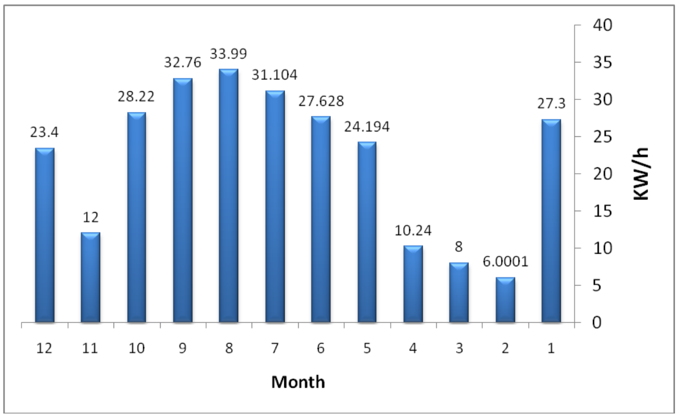

Figure 6: Energy needs

4.3 Produced Energy

Table 5 shows the monthly produced energy and the costs associated with the use of fossil fuels as backup.

Table 5: Produced energy

Month	Energy Produced [kWh]	Energy Cost (0.4D\ kWh) actual	Energy cost (0.068D\ kWh) current	Energy cost (0.332D\ kWh) Paid by the government
Jan	27.300	10.920	1856	9064
Feb	16.000	6.400	1088	5312
	8.000	3.200	544	2656
Apr	10.240	4.096	696	3400
	24.194	9.677	1645	8032
Jun	27.628	11.051	1879	9172
Jul	31.104	12.441	2115	10326
Aug	33.990	13.596	2311	11285
	32.760	13.104	2228	10876
Oct	28.220	11.288	1919	9396
	12.000	4.800	816	3984
Total	23.400	100.573	17.097	*83503*

Table 5 shows the difference between the real value of subsidized cost kWh and the actual, loss and loss on the government due to the very high support rate 83,503 dinars .Therefore, since the cost of the solar system to feed the building loads about 370,000 dinars, and compared to the value of the loss, the installation of the station means the possibility of restoring the value of the solar system in the first five years and then after 20 years free.

4.4 Design the model

Table 6: Design model

Technical data for the base module	
Area (m^2)	140
Width (m)	1.2
Length (m)	25
Height (m)	1.63
Focal length (m)	0.65
Rim angle	50^0
Weight (kg/m^2)	730

For this scenario is required a collecting surface area of 140 m2 of PTCs (5 NepSolar PolyTrough 1200 solar modules) that result in 77 kW of installed power. For the cold production it was considered an adsorption system capable of delivering 48 kW of cooling power (SorTec adsorption Chillers).

4.5 Economic analysis

For the economical analysis, was considered a system lifetime of 25 years. The analysis was carried out at constant prices (without considering the rate of inflation) it was considered a nominal discount rate of 3 %; were not considered costs associated with the maintenance of the system and it was considered an annual cost of € 2.692 with backup energy fossil fuels. The prices mentioned in table 7 refer to PTCs and to the adsorption system; and were obtained directly from their manufacturers [11].

Table 7: Acquisition cost

System	Acquisition cost	
PTCs	350,00	€/m^2
Adsorption cooling	1.250,00	€/Kw

5. CONCLUSIONS

Solar water heating reduces the amount of water that must be heated by conventional water-heating system used in buildings, so it can directly substitute fossil-fuel energy for renewable energy, allowing at the same time a reduction in the energy bill, with the possibility of achieving a better energy label for the building. The use of PTC when combined with adsorption technology can be used for building air conditioning, enabling the production of heat and cold besides the production of DHW, with environmental benefits. The existing technology enables the use of these systems in small size applications (less than 100 kW), once there are available in the market small PTCs that can be roof mounted, and small power adsorption systems (less than 10 kW).

REFERENCES

[1] Kaygusuz, K. 2011. Prospect of concentrating solar power in Turkey: The Sustainable Future, Renewable and Sustainable Energy Reviews, 15, 808-814.

[2] Blair, N., Dobos, A, Freeman, J., Neises, M., Wagner. 2014. System Advisor Model, SAM 2014.1.14: General Description, in, National Renewable Energy Laboratory (NREL)

[3] Solair, Increasing the Market Implementation of Solar Air-conditioning Systems for Small and Medium Applications in Residential and Commercial Buildings [online]. Available: http://www.solair-project.eu.

[4] Bernardo, H. 2009. Solutions to Improve Building Energy Classification in Portugal. 2nd International Youth Conference on Energetics.

[5] GECOL Annual Report 2010. General Electricity Company of Libya, Tripoli, Libya.

[6] Desideri, U., Proietti, S., Sdringola, P. 2009. "Solar-powered cooling systems: Technical and economic analysis on industrial refrigeration and air-conditioning applications". Elsevier, Applied Energy 86, 1376–1386.

[7] Wess, W., Rommel, M. "Process Heat Collectors, state of the art within task 33/I

[8] Saha, B.B., Akisawa, A., Kashiwagi, T. 2001. "Solar/waste heat driven two stage adsorption chillers", Renew. Energy 23, 93–101. https://www.alibaba.com/premium/solar_absorption_chiller.html

[9] NASA, Surface meteorology and Solar Energy [online]. Available: http://eosweb.larc.nasa.gov/sse/

[10] Quintal, E.S., Bernardo, H.S., Amaral, P.G., Neves, L.P. 2011. Use of Parabolic Trough Solar Collectors for Building Air Conditioning and Domestic Hot Water Production - Case Study, Conference Paper. DOI: 10.13140/RG.2.1.2498.7683.