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APPLICABILITY OF SOLAR AIR-CONDITIONING TECHNOLOGY IN IRAQI BUILDINGS

By:

QUDAMA MOHAMMED QASM AL- YASIRI

Internal Supervisor: Dr. Márta Szabó (PhD), Associate Professor
Department of Building Services and Environmental Engineering, Szent István University

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Prepared by

QUDAMA MOHAMMED QASM AL- YASIRI

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Outline:

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- **Objectives**
- **Building Characteristics in Iraq**
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INTRODUCTION

Iraq is located in the south-west region of the continent of Asia. It is part of the north-east of the Arab world and lies between latitudes 29 – 37 degrees north. The summer season is hot, longer daytime and the mean temperature is more than 45 ℃ most of the year.

During hot period, the buildings in Iraq need to use efficient cooling systems to overcome the high temperature and reach occupants comfort. These systems consume more than 50% of the total electric power provided by local networks. The researchers and experts are always resorting to use techniques and modern methods that reduce thermal loads in buildings, which lead in reduction of the cooling equipment sizes.

Iraq suffers from electric power shortage because of wars experienced by the country and act of sabotage. This problem maximizes during the summer due to cooling systems usage. Furthermore, these cooling systems have a negative environmental impact due to the refrigerants; these compounds have the ability to damage ozone layer and increase the global warming. It has become an urgent need to find solutions and take advantages of the great development of the technology used in this area, which relies on finding alternatives means to provide energy from other environmentally friendly sources, as well as the use of equipment that consume less electricity.

One of the trends that have attracted researchers in this field is the exploitation of abundant solar energy. Solar energy can be utilized to generate the necessary electrical power to operate the various cooling systems, and thereby reducing dependence on traditional sources. On the other hand, solar energy can enter directly into cooling applications by means of special equipment that deal with the thermal energy. However, the utilization of thermal energy expanded in recent years to cover many cooling applications, notably in cooling of building. The main reason of using solar thermal cooling systems is that they use the thermal energy entirely to drive cooling systems and reduce dependence on electrical energy quite dramatically, or it can be used as an adjunct to other cooling systems in terms of reducing the required power supply to nearly 50%.

This research explains the most important solar cooling systems that are used to cool buildings instead of the traditional ones and how important it is to dispense or reduce the electrical energy spent on cooling, as well as how to minimize the heat gain of buildings which greatly help in choosing the right system for different building types.

OBJECTIVES

The main objectives of the research can be summarized in the following:

- Evaluating the main available solar cooling systems based on the technical, operational, availability, environmental and economic point of view.
- Calculating and analyzing the cooling loads for a certain building using two methods.
- Studying the possibility of using solar air- conditioning systems instead of the traditional ones through a case study educational building.
- Defining a set of simple construction techniques to minimize cooling loads as a kind of building retrofitting for better energy and cost effectiveness.
- Estimating and then evaluating the environmental and economic impacts associated with the use of traditional and solar air- conditioning systems.
- Assessing the different types of air- conditioning systems in terms of initial cost and the operational lifetime for each type which has a major role in choosing convenient air-conditioning system(s) for different applications.

4. CASE STUDY & CALCULATIONS

4.1 Building case study

The building sector in Iraq is one of the most important sectors responsible for energy consumption due to population growth and increasing of various other economic activities year after year. Residential buildings come in the front of buildings in terms of the rate of energy consumption. A study reported that the energy consumed by the residential buildings in the capital- Baghdad alone was about (48%) of the total energy supplied to the city [103]. It has a very high percentage when compared to other sectors (industry 29%, agriculture 4%, trade 6% and government buildings 13%). It is also stated that in the year 2002, the buildings in Baghdad city consumed (92%) of the total energy processed to operate air-conditioning and cooling systems due to the long summer season in Iraq which is characterized by high-temperature and long day hours. [104]

The chapter deals with a building case study located in the southern part of Iraq which is one of the hottest regions in the country. The following are the main details to the building:

4.1.1 Building location

The building is located in Maysan province to the north of Amarah city (Maysan province center) on the main line linking the city to the capital Baghdad (Amarah city located south-east of Iraq, on a low ridge next to the Tigris River waterway south of Baghdad about 50 km from the border with Iran). The building shown in fig.(1) is used for educational purposes at Maysan University – Faculty of Engineering.

Fig. (1): Building case study

4.1.2 Building specifications

The building was established in 2012 by the ministry of housing and reconstruction with the supervision of engineers and technicians staff from Maysan University. Total building area is ($66.37 * 20\ m^2$) and consists of two floors, basement and upper floor. The specifications of the building construction materials can be summarized in table (1).

Table (1): Building construction materials.

Parameter	Specification (from outdoor to indoor)
Roof:	
Type	Flat
Construction	(4 cm) high density concrete shtyger (10-20 cm) dry sand. (1 mm) roofing insulation (5 cm) cork (6 mm) mastic (18 cm) high density concrete. (5 mm) Juss plaster (30 cm) air gap (5 mm) acoustic tiles in suspended ceiling
Ceiling height	(3 m)
Roof area	(1,327.4 m^2) (Total building area)
Wall:	
External wall:	
Construction	(2 cm) Cement layer (23 cm) Brick (1.5 cm) Cement layer (2-4 mm) Juss plaster (2 cm) granite (only for two walls)
Internal wall:	
Construction	(2-4 mm) Juss plaster (2 cm) Cement layer (23 cm) Bricks (2 cm) Cement layer (2-4 mm) Juss plaster
Window:	
Area	(1.5 * 2 m)
Glazing type	Clear, single glazing of (6 mm) width
Frame material	Aluminum.

4.1.3 Climate Conditions

The building is located in the latitude (31.83 N) and longitude (47.15 E) at an open area where it is not surrounded by any buildings. The climate is hot and characterized by high direct solar radiation and long daylight hours during most days of the year, see table (2).

Table (2): Solar radiation & daylight hours for the location [105]

Lat. 31.83 Lon. 47.15	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Averaged Daylight Hours (hrs.)	10.3	11.1	11.9	12.9	13.7	14.1	13.9	13.2	12.3	11.4	10.5	10.1
Monthly Averaged Direct Normal Radiation ($kWh/m^2/day$)	5.30	6.32	5.64	5.52	6.51	8.08	7.44	7.41	6.70	5.30	4.56	4.68

The climate surrounded the building is tough due to the high temperature range especially during summer season, which usually reach more than 50 ℃ and the weather still hot until the night period, so it requires the use of air-conditioning units as well.

Cooling profile during the year can be seen in fig. (2), based on the data of table (3).

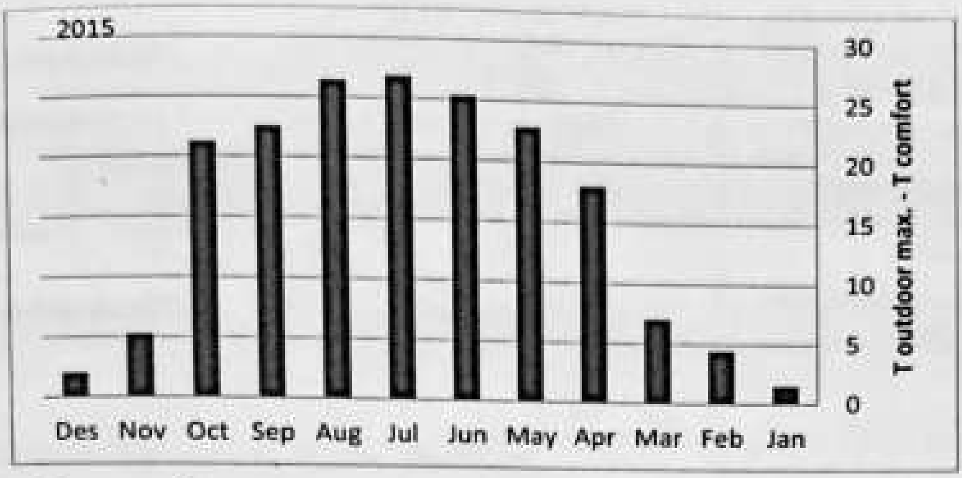

Fig. (2): Monthly averaged temperature difference ($T_{outdoormax} - T_{comfort}$) characterizing cooling profile during the year 2015.

Table (3): Max. Temperature recorded in Amarah city during 2015 [106]

2015	Jan.	Feb.	Mar	Apr	May	Jun.	Jul.	Aug	Sep.	Oct.	Nov	Dec.
Max. Temp	25.5	28.4	31	42	46.8	49.3	50.8	50.4	46.5	45.2	29.2	26
T_{dif}*	1.5	4.4	7	18	22.8	25.3	26.8	26.4	22.5	21.2	5.2	2

***T difference = Max. Outdoor temperature – Comfort temperature (24 ℃).**

4.1.4 Specifications of air-conditioning systems used in the building

Cooling systems used in building are air cooled vapor compression air- conditioning systems types which are driven by electrical energy. They are used for air-conditioning purposes in the building during the summer and winter, where they work to provide cool air during the summer period and warm air in the winter period with controlling the humidity level during the year.

The general aspects of those systems are listed in table (4), as the technical information is taken from the name plate that is fixed on each air-conditioning system.

Peak load:

• The peak load can be identified by the sum of total load of the roofs, exterior walls and windows of each room at different times, as follows:

Room	Time / Q(kW)	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00
R1	Roof	0.561	0.615	0.686	0.758	0.794	0.829	0.847	0.829
	Ext. walls	1.945	1.999	2.109	2.253	2.466	2.59	2.663	2.874
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.735	0.702
R2	Roof	0.244	0.268	0.299	0.33	0.346	0.361	0.369	0.361
	Ext. walls	0.702	0.719	0.752	0.802	0.881	0.929	0.992	1.04
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R3	Roof	0.244	0.268	0.299	0.33	0.346	0.361	0.369	0.361
	Ext. walls	0.685	0.702	0.702	0.735	0.798	0.829	0.891	0.939
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.37	0.351
R4	Roof	0.582	0.638	0.712	0.786	0.823	0.861	0.889	0.861
	Ext. walls	0.78	0.78	0.78	0.815	0.919	0.989	1.094	1.164
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.745	0.702
R5	Roof	0.721	0.789	0.882	0.974	1.02	1.066	1.089	1.066
	Ext. walls	1.133	1.15	1.183	1.251	1.388	1.475	1.596	1.682
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.735	0.702
R6	Roof	0.733	0.803	0.897	0.99	1.037	1.084	1.107	1.084
	Ext. walls	1.116	1.133	1.133	1.184	1.305	1.375	1.495	1.571
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.76	0.702
R7	Roof	0.529	0.58	0.647	0.715	0.749	0.783	0.799	0.783
	Ext. walls	1.138	1.155	1.188	1.257	1.394	1.481	1.63	1.69
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.74	0.702
R8	Roof	0.244	0.268	0.299	0.33	0.346	0.361	0.369	0.361
	Ext. walls	0.344	0.344	0.344	0.36	0.406	0.437	0.483	0.514
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R9	Roof	0.253	0.278	0.31	0.342	0.358	0.375	0.383	0.375
	Ext. walls	0.706	0.723	0.723	0.756	0.822	0.854	0.919	0.969
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R10	Roof	1.194	1.309	1.461	1.614	1.69	1.766	1.804	1.766
	Ext. walls	3.382	3.469	3.469	3.678	3.995	3.995	4.455	4.608
	Co. window	1.338	1.47	1.47	1.535	1.535	1.47	1.47	1.404
R11	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.452	0.483	0.498	0.498	0.498	0.498	0.498	0.498
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R12	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.876	0.918	0.933	0.954	0.974	0.974	0.995	1.001
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R13	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.452	0.483	0.498	0.498	0.498	0.498	0.498	0.498
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R14	Roof	0.222	0.243	0.271	0.299	0.314	0.328	0.335	0.328
	Ext. walls	0.479	0.511	0.528	0.528	0.528	0.528	0.528	0.528
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R15	Roof	0.222	0.243	0.271	0.299	0.314	0.328	0.335	0.328
	Ext. walls	0.479	0.511	0.528	0.528	0.528	0.528	0.528	0.528
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R16	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.452	0.483	0.498	0.498	0.498	0.498	0.498	0.498
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R17	Roof	0.222	0.243	0.272	0.299	0.314	0.328	0.335	0.328
	Ext. walls	0.479	0.511	0.528	0.528	0.528	0.528	0.53	0.528
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351

R18	Roof	0.243	0.266	0.297	0.328	0.343	0.359	0.377	0.359
	Ext. walls	0.551	0.588	0.607	0.607	0.607	0.607	0.61	0.607
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R19	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.452	0.483	0.498	0.498	0.498	0.498	0.498	0.498
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R20	Roof	0.222	0.243	0.272	0.299	0.314	0.328	0.335	0.318
	Ext. walls	0.479	0.511	0.528	0.528	0.528	0.528	0.538	0.528
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R21	Roof	0.214	0.235	0.262	0.289	0.303	0.317	0.323	0.317
	Ext. walls	0.887	0.939	0.995	1.035	1.076	1.097	1.137	1.126
	Co. window	0.335	0.367	0.367	0.384	0.384	0.367	0.367	0.351
R22	Roof	0.455	0.499	0.557	0.615	0.644	0.673	0.688	0.673
	Ext. walls	0.997	1.065	1.099	1.099	1.099	1.099	1.099	1.099
	Co. window	0.669	0.735	0.735	0.768	0.768	0.735	0.75	0.702
Q_{Total} (kW)		37.52	40.01	41.51	43.835	45.707	46.313	47.986	47.952

- The peak load at the time (**18:00**).

Total load:

R.	Q_{Roof} (kW)	Q_W(kW) (Ext+Int)	Q_G(kW) (Con+Sol)	$Q_{occupants}$ (kW)		Q_{Light} (kW)	Q_{Equip} (kW)	$Q_{Infiltration}$ (kW)		RSL (kW)	RLL (kW)	RTL (kW)
				Sensible	Latent			Sensible	Latent			
R1	0.847	2.951	3.504	0.075	0.055	0.446	1.61	0.991	0.196	10.424	0.251	10.675
R2	0.369	1.091	1.752	0.15	0.11	0.194	1.435	0.448	0.088	5.439	0.198	5.637
R3	0.369	0.99	1.752	0.15	0.11	0.194	1.435	0.448	0.088	5.338	0.198	5.536
R4	0.879	1.396	3.504	0.075	0.055	0.463	1.61	1.023	0.202	8.95	0.257	9.207
R5	1.089	1.826	3.504	0.3	0.22	0.573	3.265	1.247	0.247	11.804	0.467	12.271
R6	1.107	1.98	3.504	0.75	0.55	0.68	1.835	1.279	0.253	11.135	0.803	11.938
R7	0.799	1.99	3.504	1.875	1.375	0.491	1.235	0.927	0.183	10.821	1.558	12.379
R8	0.369	0.582	1.752	0.15	0.11	0.194	4.15	0.448	0.088	7.645	0.198	7.843
R9	0.383	1.185	1.752	0.15	0.11	0.202	3.075	0.448	0.088	7.195	0.198	7.393
R10	1.804	5.165	7.008	3	2.2	1.263	3.175	2.59	0.512	24.005	2.712	26.717
R11	0.323	1.011	0.528	0.075	0.055	0.17	1.235	0.352	0.07	3.694	0.125	3.819
R12	0.323	1.301	0.528	0.225	0.165	0.17	1.825	0.352	0.07	4.724	0.235	4.959
R13	0.323	0.597	0.528	0.225	0.165	0.17	1.825	0.352	0.07	4.02	0.235	4.255
R14	0.335	0.631	0.528	0.225	0.165	0.176	1.825	0.384	0.076	4.104	0.241	4.345
R15	0.335	0.631	0.528	0.225	0.165	0.176	1.825	0.384	0.076	4.104	0.241	4.345
R16	0.323	0.597	0.528	0.225	0.165	0.17	1.825	0.352	0.07	4.02	0.235	4.255
R17	0.335	0.631	0.528	0.225	0.165	0.176	1.825	0.384	0.076	4.104	0.241	4.345
R18	0.367	0.72	0.528	0.225	0.165	0.193	2.625	0.416	0.082	5.074	0.247	5.321
R19	0.323	0.597	0.528	0.225	0.165	0.17	3.105	0.352	0.07	5.3	0.235	5.535
R20	0.335	0.631	0.528	0.15	0.11	0.176	1.83	0.384	0.076	4.034	0.186	4.22
R21	0.323	1.334	0.528	0.15	0.11	0.17	1.83	0.352	0.07	4.687	0.18	4.867
R22	0.673	1.732	1.056	0.3	0.22	0.362	2.03	0.799	0.158	6.952	0.378	7.33
Σ_T	12.333	29.57	38.4	9.15	6.71	6.979	46.43	14.71	2.909	157.57	9.619	167.19

* The total cooling load of the building = **167.19 kW** = 167.19 kW/ 3.517 ≈ **47.5 tons**.

4.2.2 Hourly Analysis Program (HAP)

HAP program is one of the most important software programs that are used in the design of air conditioning systems in Iraq.

The program was developed by Carrier Company where it is uses to design air-conditioning systems (cooling and heating) of various buildings and makes selection of

5. CONCLUSIONS

In recent years, there were great interests in the study of solar energy and its practical applications as an important sustainable energy source which can make a unique boom in many areas of life.

Iraq has a great potential of solar energy which gives it the opportunity to be a solar leader if it is tapped properly. At the same time, the country suffers from a significant shortage in electric power production, where the produced power covers almost the half of required power due to several reasons, and this problem is exacerbated in the summer largely because of air conditioning systems usage, where they consume the largest percentage of supplied electric energy.

One of the most important goals of this research was finding a way to take advantages of the availability of solar energy on one hand, and solve the problem of power shortage that affects negatively on people's comfort on the other hand.

The research has been studied for building in Iraq in order to assess the current situation of its air conditioning systems and recommend the possibility of using other modern technology that has many advantages. Several conclusions have been derived and can be summarized as follow:

- The possibility of using environmentally friendly air-conditioning systems has been studied by conducting detailed calculations of overall cooling loads of the building. These calculations are very important to choose the number and size of A/C systems that must be used as a substitute for conventional systems. The calculations of cooling loads have been made by two methods and the results were approximately the same. The total loads result by CLTD/SCL/CLF method was (167.19 kW), while it was (165.6 kW) by using HAP software.

  Furthermore, the calculations showed how bad is the cooling loads estimation for several rooms of the building which is reflected negatively on choosing the right A/C systems. For example, the calculations showed that room No. 1 needs a cooling system capacity of (10.675 kW), while the existing systems provide around (24 kW) capacity, and the situation is similar to other rooms of the building.
- The calculations were carried out as a kind of building retrofitting are very important and reflect positively in reducing the need for cooling by 14%. That reduction is led to reduce the number of solar absorption chillers that need to cool the building from

5 to approximately 4 chillers. Although it was simple and a bit expensive but it is more economical if compared with the rationalization in the air-conditioning systems usage.

- Economically, it was found that the use of traditional A/C systems of the building consumed about (1,438.8 kWh) of electric power for each day work. While the proposed solar absorption chillers consumed only (165 kWh) for each day work. And from an environmental perspective, CO_2 emissions that linked to the amount of electricity consumed by the traditional systems were about (1442.88 kg), but the generated CO_2 emissions from solar ones were (165.47 kg) only.
- The initial cost of A/C systems is one of the most significant aspects to choose the appropriate system. From this perspective, the initial cost of traditional systems constitutes about 10% of the initial cost of solar A/C systems. Also, the fact that traditional systems are more efficient than those driven by solar, and an easy installation and maintenance. On the other hand, the operating lifetime of the solar A/C systems represents approximately 3 times more than the operational lifetime of the traditional ones as they contain moving parts much lower than those found in conventional systems as well as other electrical problems associated with traditional systems.

As a result, it can be concluded that the main problem facing the solar A/C systems in general is the cost. Also, they still need more improvements to increase the total system efficiency. But, it could be a rival to traditional systems when taking into consideration the electric power consumption, long operating lifetime and positive environmental impact. Likewise, the type of application is essential to examine the feasibility of their use, as applying such systems in buildings that have more daily working hours, like hospitals or airports; they are definitely going to be highly interesting.

6. SUMMARY

Solar radiation is available largely in Iraq during most days of the year. This feature opens broad prospects for the exploitation of this wealth and benefit from the rapid scientific development of the advanced world. Especially that Iraq has not been able to fully utilize this golden opportunity and still depends on fossil sources like oil and natural gas in most of life applications.

Iraq has experienced many long wars which affected its infrastructure, especially the electricity sector. There is lack of supplying the necessary electric power for daily life of the people. And this lack is evident during the hot summer period because of the heavy reliance on air conditioning systems that are known to consume large electric power.

Air-conditioning systems are the technology that cannot be dispensed with in a country like Iraq because of the harsh weather conditions. But, the economic and environmental impacts of this technology have led many scientists and researchers to find radical solutions to solve the problem. One of these solutions is the integration of solar cooling technology to reach results more acceptable in terms of protecting the environment and reducing power consumption rates.

In this research, it has been reviewed in details the most important traditional air conditioning systems used in the Iraqi buildings, and the advantages and disadvantages of these systems have been stated for the sake of comparison among them. Later, three air-conditioning systems powered by solar thermal energy have been reviewed in details, where they are compared based on the basis of performance, driving temperature range, availability, applicability, in addition to the cost and its impact on the environment. It was found that the solar absorption systems are the best which may compete with the traditional ones.

Cooling load estimations have been done for a certain building in Iraq by two methods: The first by using Cooling Load Temperature Difference/ Solar Cooling Load/ Cooling Load Factor method (CLTD/SCL/CLF) of ASHRAE organization, where it is a traditional method used to calculate cooling and heating loads for buildings, according to the tables provided by ASHRAE. The second method was by using Hourly Analysis Program (HAP) that was developed by Carrier Company. This program is number one used in Iraq to calculate the cooling and heating loads as well as analyzing fuel and energy consumption by the building. The program has been used to calculate the cooling loads only in order to compare the results that were obtained in the first method, and they were too close together by the two methods. Then, solar absorption chillers provided by a professional company special to manufacture refrigeration systems in China were selected to meet the building total cooling loads.

It has been mentioned that many techniques can be applied to minimize the external cooling loads entering the building. Building retrofitting was conducted to improve building energy by minimizing cooling loads through the building envelope (roofs, walls and windows), which has a positive effect on air-conditioning systems in economic terms.

Moreover, the magnitude of electrical energy consumed by building cooling systems has been estimated based on the technical information provided by the manufacture companies of the systems during the operating hours of each day work. Then, the magnitude of CO_2 emissions was calculated from the consumed electrical power for both traditional and solar air-conditioning systems.

Finally, the traditional and solar air-conditioning systems were evaluated on the basis of initial cost and operational lifetime period separately to indicate the economic side, which is the most important aspect in choosing the appropriate air-conditioning systems for each application. Despite numerous advantages of using solar thermal systems, but it remains limited to use due to its high cost compared with the other conventional systems.

Generally, many of the well-known companies that manufacture the traditional air-conditioning systems have started working to produce solar thermal air-conditioning systems recently, and work to develop them in order to decrease the total cost to compete with the traditional ones and gain satisfaction of the consumers.

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