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Proposed Energy Saving Techniques for Multi-Apartment Buildings in Jordan

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Abstract

During the last decade and as a result of the significant increase in the population of Jordan, multi-apartment buildings became the most dominant building format, especially in Amman the capital of Jordan. The lack of well-developed passive heating, cooling and energy saving solutions, made the reliance on central heating in winter and air conditioners in summer the prominent choice for residents. The sustained significant increase in the use of these high energy-consuming systems, have started to exert a heavy toll on the national economy and have raised environmental and public health concerns. This study is devoted to the analysis of heating and cooling problems in the new multi-apartment buildings in Jordan. The main focus of this study is to minimize fuel and electricity consumption. Techniques for heating and cooling are proposed. This study shows that the proposed techniques will lead to significant savings in total energy consumption. These savings will lead to multifold benefits including a welcomed relief to lower and middle class family budgets, a significant reduction in the national reliance on imported energy, and a significant reduction in greenhouse emissions. Nevertheless a wider and more specific study could be done for optimizing the loads and choosing the best air conditioning system.

Keywords: *Energy Management, Multi-Apartment, Building Energy Saving, Renewable energy.*

1. Introduction

Jordan is a developing non-oil producing country located in the Middle East. Jordan imports 95% of its energy from neighboring countries. In general, large cities are comprised of high-rise and multi-apartment buildings, where the application of passive heating and cooling techniques is a difficult task. Energy consumption for residential purposes accounted for 18% of the total consumed energy in 1999. By 2009, energy consumption for the residential sector jumped to 30% [Amman Chamber of Industry 2009], and is projected to increase if energy saving techniques are not implemented.

The scientific community expects that the world will start to face critical shortages in its supply of fossil fuel in the near future, with the expectation for most oil resources to vanish within the next 50 years [Canty 2009]. The significant increase in demand for energy by several emerging nations has driven the global energy consumption to unprecedented levels. As a result, the cost of energy has reached new levels and is expected to continue to rise. The ramifications of this large increase in energy cost, will pose serious challenges to the economies of most developing nations.

Harmful emissions from fossil fuel are causing serious environmental and health problems, and are believed to be the main culprit behind the global warming phenomenon. In an attempt to save the planet from the predicted catastrophic effects of global warming, international organizations and world governments started to allocate more funds for renewable energy and energy saving research. During the last 30 years researchers have tackled the issues of saving energy in buildings, energy efficient devices, and passive heating and cooling techniques. Some researchers worked on improving the performance of the equipment and appliances used in buildings [Sezai et. el. 2005]. Beithou 2005 tried to save energy by managing the operation of energy consuming devices using programmable logic control. Abrahamse 2005 discussed household energy conservation and energy efficient buildings.

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About 60% of the energy consumed within a building goes for heating and cooling purposes [Jaber 2002]. Thus, it is essential to analyze the thermal behavior of the building. Guglielmini et.al studied the influence of the thermal inertia of building structures on comfort and energy consumption. Many other researchers [Alajmi 2009 and Mickael 1986] studied saving energy by using solar, wind, and geothermal energy sources. In all previously mentioned studies and in many others, the objective was the reduction of energy consumption.

During the last decade and as a result of the large increase in population, there was a large increase in multi-apartment building construction in Amman. A changing climate requiring more heating and cooling and an improved standard of living, have lead to huge increases in energy consumption, raising the need to address concerns of a continuously increasing demand for energy. In addition to the environmental and energy concerns, externally fitted air-conditioners are scarring the façade of buildings. In this study, solutions for saving energy in multi-apartment buildings are proposed, with the objective being to reduce fossil fuel consumption and toxic emissions.

2. Description of Problem

Jordan is a developing country in the Middle East. Its population is expected to grow at a rate of 2.264% in 2009. During the past decade there was a great increase in the construction of multi-apartment buildings. Amman, the capital of Jordan, is becoming increasingly populated by multi- apartment buildings Fig. 1.

Studies show that approximately 45,000 new residential apartments are needed every year to cover the natural population growth. Due to the zoning regulations, the majority of these apartments are located in four to eight story buildings, with each floor consisting of two to four apartments Fig. 2. The main problem in using passive heating and cooling in these types of structures is that orientation is not possible for the building and its apartments at the same time.

The proposed techniques will accomplish the following benefits:

1. Reduction in the amount of energy consumed, which will lower the electric energy bill for consumers;
2. Reduction in toxic gases emitted, which will result in a cleaner environment;
3. Reduction in the amount of total energy imported by the country, which currently exhausts the annual national budget.

3. General Nature of Energy Consumption

Most families use central heating or separate heating units for heating purposes. Apartments in Jordan are generally large in area ranging between 150 m^2 to 400 m^2. Large apartments require a great amount of energy for proper heating and cooling. The high cost associated with heating and cooling the entire apartment leaves most residents no choice but to selectively restrict its use to specific sections of the apartment, generally the living room.

Heating related problems can be summarized as:

1. Apartments are oriented in different directions (there will always be difficulty in orientation for passive solar heating in multi-apartment buildings);
2. Large size apartments, requiring a significant amount of energy (most of which is wasted);
3. The poisonous gasses emitted from boilers and its effects on the environment.

Cooling related problems can be summarized as:

1. Apartments are oriented in different directions (adequate cooling is not achieved);
2. Even though most apartments have large windows, cultural and privacy issues take away the option of opening windows at night preventing people form taking advantage of the relatively cool weather outside;
3. Amman is a modern city where buildings have an attractive external architecture accentuated by decorative stones. Now fitting split unit air-conditioners scars this nice view. Recently architects started influencing the general opinion of the country towards stopping this practice, but alternatives have yet to be proposed;
4. Additionally, since split units are fitted near neighboring apartments in multi-apartment buildings, a noise problem exists;

Noting that complete passive heating and cooling of all the apartments in the building will be infeasible this study proposes a practical and attainable solution by heating or cooling only the living room of each apartment. This option will be adopted in this study for the heating and cooling load analysis.

4. Proposed Heating and Cooling Techniques

Actually the general weather of Amman around the year is quite nice; it is neither extremely hot nor extremely cold. The analysis of the weather outlook of Amman reveals that during the winter months, when heating is needed, there are only a few days with fully cloudy skies. Otherwise, it is mostly sunny. Table 1 shows a

sample solar radiation in the winter period. Table1 demonstrates that very good solar radiation is available through the winter-autumn seasons. These values of solar radiation encourage the use of solar energy for heating purposes.
Also, during the summer season only a few days are very hot and almost all evenings have a comfortable outdoor temperature. Table 2 shows sample outdoor temperatures in the summer period. The sample temperatures in table 2 indicate that the outdoor temperatures are quite cool, especially in the evening period. None of the temperatures exceeded 30 ^oC in August and September. The rest of the data used for the analysis are taken from Jordan's Meteorological Department.

Taking the data in Table 1 and Table 2 into consideration, it is clear that solar heating can be used in winter and fresh cool air can be used in summer. After analyzing the solar radiation in Jordan on cold days, it was found that solar energy is almost available all year round. Thus a device powered by solar energy is proposed for heating the living rooms of the different apartments in multi-apartment buildings. Figure 3 illustrates the proposed device for heating purposes.

The device consists of:

1- A 2 m^2 solar panel for each apartment (the solar panel will be capable of collecting about 1.5 kW of energy, which is more than sufficient for heating the living room);
2- Connecting Pipe: used to connect the solar panel to the radiator in the living room (this connection allows the use of the central heating system in case of very cold weather and can be used separately on sunny days);
3- Circulating Pump: used to circulate water within the pipes and pumps hot water from the solar collector to the radiator (this pump is a low duty hot water pump with speed control, to control the heat added to the living room);
4- Thermostat: used to sense the temperature in the solar panel and control the speed of the pump accordingly;
5- Hot Water Storage Tank (HWST): the HWST is used to collect excess energy inside it in case of high solar radiation and reuses it when the weather becomes cold.

In the heating device the solar radiation falls on the solar panel where heat is stored in the water. As the temperature of the water increases, the circulating pump starts working and sends the hot water to the radiator or under floor network in the living room. In case of low temperatures the central heating system will work and the solar panel will help to save energy, while if the temperature in the panel is sufficient the central heating system will be switched off and heating will be executed by the solar panel.

For cooling purposes, after analyzing the temperatures in the summer period, a device using a fan and an evaporative cooling process have been proposed. Figure 4. illustrates the proposed device for cooling purposes.
The device consists of:

1- A Low-wattage Fan: used to draw air through water in the ducted device and push it to the living room;
2- Water Filter: used for two purposes in this device, first it filters the outside air from impurities and cools the water to a lower temperature than it is out side by evaporative cooling process;
3- Ducts and Diffusers: used to drive the air and distribute it with the suitable velocities inside the living room.

5. Analysis

In order to achieve a better understanding of the problem, a sample living room shown in figure 4 has been taken for analyses. Here it will be assumed that one side of the living room is facing the outside. To visualize the energy saving aspects of the proposed devices, the heating and cooling loads must be calculated.

a- Heating Load of the Living Room

Living room dimensions are taken as 5m x 4m x 3m with one window 1.5m x 1.2m double glass windows. The out side design conditions (ASHREA 2001),

$$T_o = 5\ ^oC, RH = 35\% \quad (1)$$

The inside Design conditions

$$T_i = 20\ ^oC, RH = 50\% \quad (2)$$

Unheated space temperature T_u=12 ^oC. The overall heat transfer coefficients for external wall U_{ex}=0.467W/m^2 ^oC, internal wall U_{in}=1.24 W/m^2 ^oC, Ceiling U_c=0.47 W/m^2 ^oC, and Windows U_w=3.6 W/m^2 ^oC.

The room is taken as extreme room where the heating load is calculated for the last floor. The heat load is calculated using Carrier E20-II Block load 3.05 Program for air conditioning. The total calculated heating load for the living room is about 800 W. The solar intensity at the Applied Science University (ASU) was recorded for the winter period and sample results are listed in Table 1.

The daily average solar intensity was calculated for the various months in the winter period. Sample calculations for December and January were performed.

1- December

The average daily solar intensity in December was found to be about 700 W/m^2, for a 2 m^2 solar collector which was proposed with 60% efficiency. The total expected energy saving in January for the daytime period from 8 am to 5 pm was calculated as:

Required energy for heating the setting room (Heating Load) = 800 W/m^2
Achieved Solar Energy = Solar Intensity x Collector Area x Collector Efficiency
= 700 x 2 x 0.6 = 840 W/m^2

Expected energy saving (EES)

$$= \frac{Achieved\ Solar\ Energy}{Required\ Heating\ Load} \quad (3)$$

=840/800 = 1.05

This means that solar energy in December will be more than sufficient to cover the energy needed during the daytime.

2- January

The average daily solar intensity in January was found to be about 635 W/m^2, for a 2 m^2 solar collector which was proposed with 60% efficiency. The total expected energy saving in January for the daytime period from 8 am to 5 pm was calculated as:

Required energy for heating the setting room (Heating Load) = 800 W/m^2
Achieved Solar Energy = Solar Intensity x Collector Area x Collector Efficiency
= 635 x 2 x 0.6 = 762 W/m^2

Expected energy saving (EES)

$$= \frac{Achieved\ Solar\ Energy}{Required\ Heating\ Load}$$

= 762/800 = 0.95

This means that about 95% of the energy needed during the daytime will be covered by solar energy.

Therefore, on average, solar energy is expected to be almost sufficient for heating the living room without using large collector area. This will eliminate the need to use external heaters during the daytime which represents the longest period where heaters are used. By saving this amount of energy, lower fuel consumption and lower gas emissions will be achieved.

b- Cooling Load of the Living Room

The out side design conditions (ASHREA 2001), $T_o = 38^oC$,

The inside Design conditions

$T_i = 22^oC, RH = 50\%$

Unheated space temperature $T_u = 31^oC$

The calculation of the cooling load is performed again by Carrier E20-II, where no solar gain is considered as there will be no solar radiation for cooling in the night period from 6 pm to the morning hours.

Thus the average cooling load of the setting room is found to be 910 W.

For ventilation purposes 1 ACH is implemented for the living room, which makes $60m^3/h$. This air supply will generate an air motion within the living room. To interpret the air motion in terms of comfort, the local air temperature in accordance to the terminal velocity should be estimated [McQuiston et.al. 2000],

$$\Delta T_x = 0.8 * \Delta T_o \frac{\overline{V}_x}{\overline{V}_o} \quad (4)$$

where

ΔT_x: The difference between the local stream and room temperatures.

ΔT_o: The difference between the outlet air and room temperatures.

$\overline{V}_x$: Local air velocity.

$\overline{V}_o$: Terminal air velocity.

Temperatures calculated using equ. 4 show that the temperatures within the entire occupied space will be 1 ^oC less than room temperature. This equation will allow us to determine the outside air temperatures that will be suitable for outside air supply in summer. In this study all temperatures below or equal to 25 ^oC will be accepted for outside direct cooling.

To calculate the energy savings by this method, a survey on the outside temperature records for the period between May and October 2008 was performed.

Based on the assumption that air conditioners are used for only 6 hours, the resulting cost in the month of May would be:

6 h/day*30 days/month*3.5 kW*0.031 JD/kWh= 19.5 JD/month

The number of hours where outside air temperature is less than or equal 25 =105 h.

Energy consumed cost:

105h/month * 0.3 kW* 0.031 JD/kWh= 0.976 JD/month+75 h/month * 3.5 kW * 0.031 JD/kWh=8.1375

The total cost = 9.1 JD/month

The cost saving is 19.5-9.1=10.4 JD/month

Saving percentage= 53%

6. Conclusion

Recently multi-apartment buildings have been increasingly spreading throughout Jordan. These buildings consume an estimated 30% of the country's total energy. For obvious economical and environmental reasons this consumption rate must be reduced. In this study, highly efficient heating and cooling techniques are proposed. The proposed techniques are presented in the form of devices that can be used as separate units for each apartment or a central unit for the entire building. Based on the weather conditions in Jordan, an estimated

95% of the heating required for the living room in winter can be recovered from the sun directly. In the case of cooling, the proposed device, if used in a central manner, will reduce about 55% of the cooling load required and eliminate the noise and unappealing view created by external split units. Finally we highly recommend the integration of energy saving techniques into building codes and requiring contractors to implement such techniques to better protect our environment and reduce energy consumption. Much precise investigations are advised to be performed for choosing the best air conditioning system.

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Figure 1. Building Density in Amman.

Figure 2. A Picture indicating that most Buildings are Multi-Apartment Buildings.

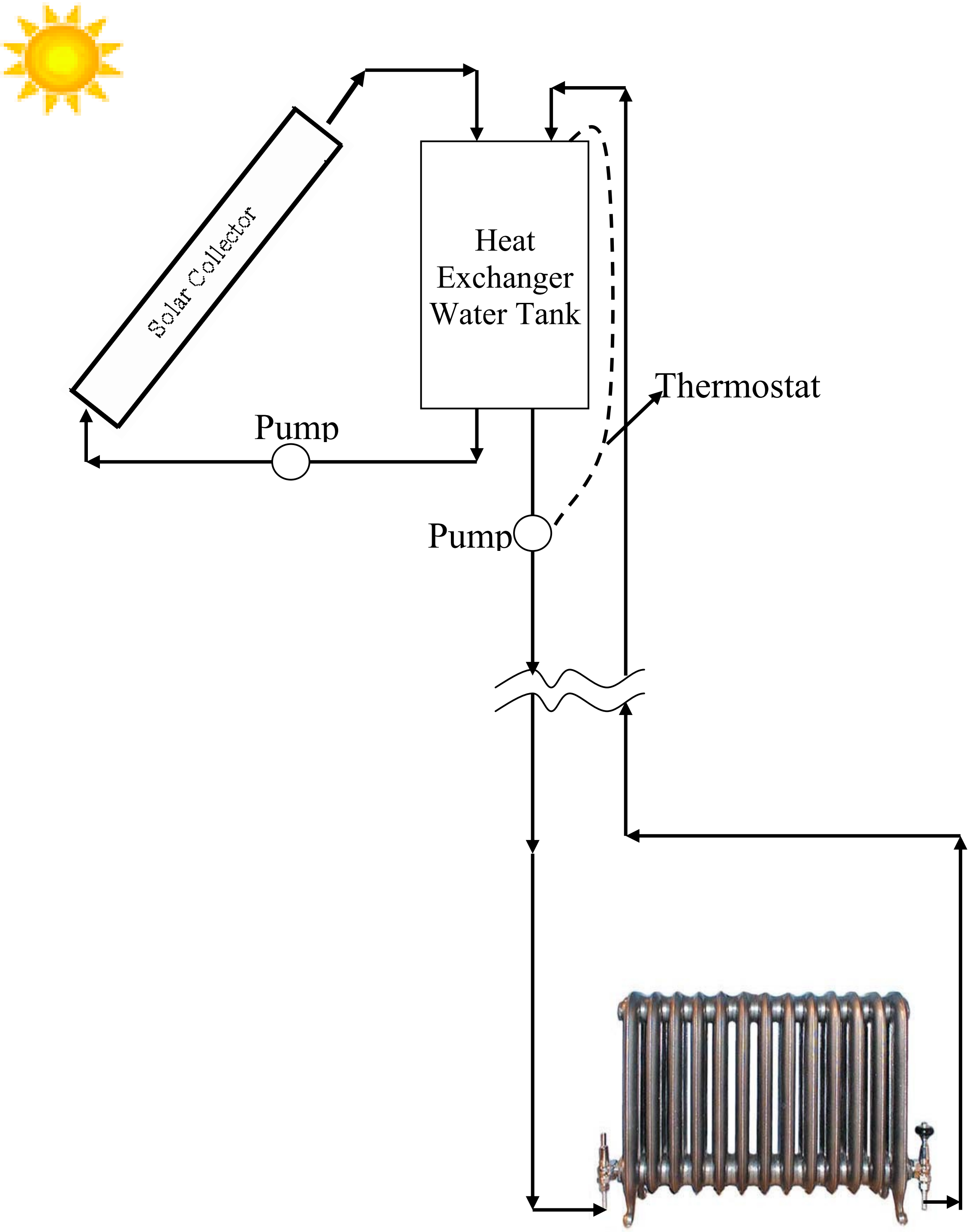

Figure 3. Schematic diagram for the proposed Heating device in the multi-apartment buildings.

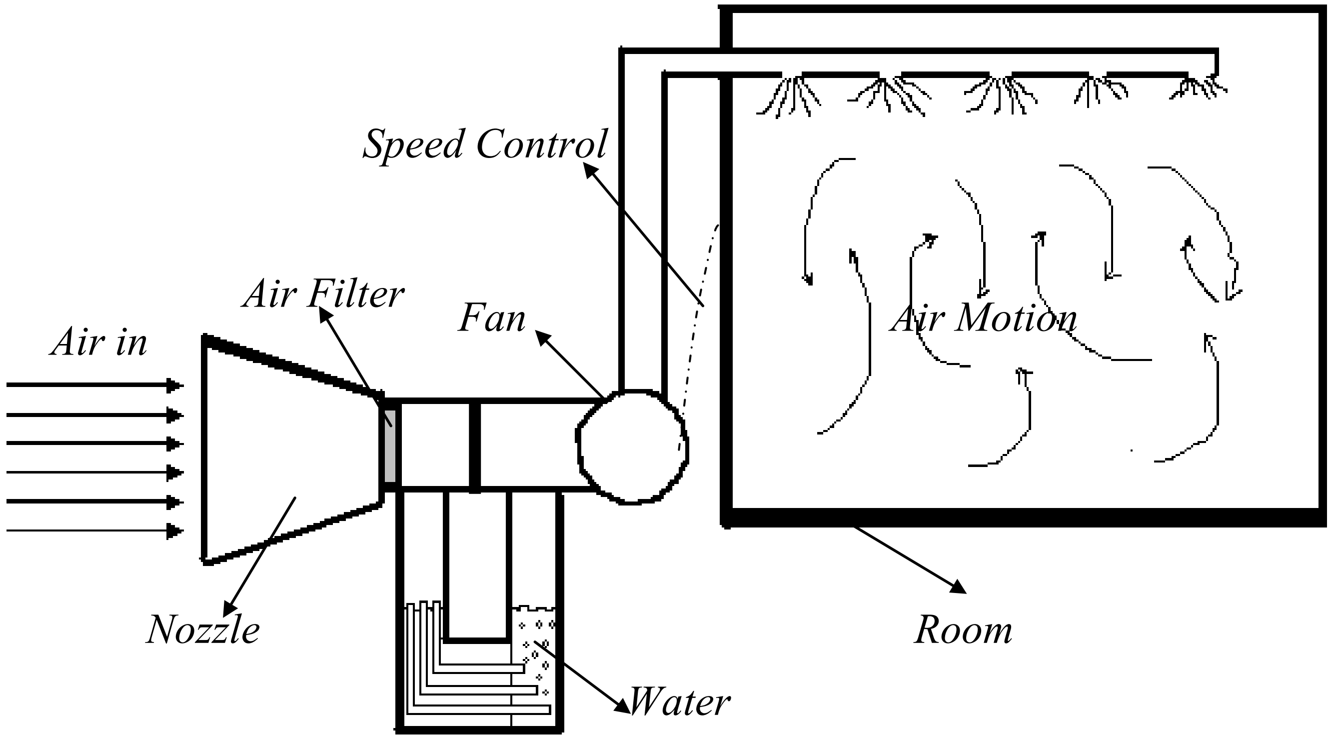

Figure 4. Schematic diagram for the proposed cooling device in the multi-apartment buildings.

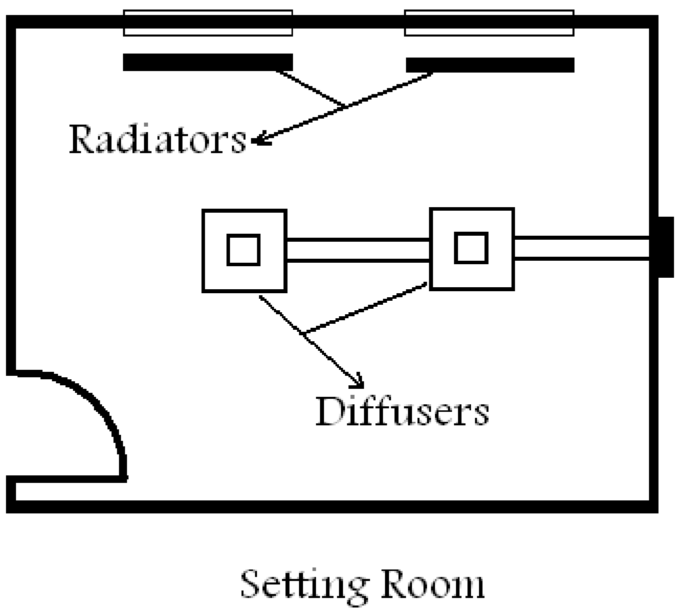

Figure 5. A Sample Living Room (5m*4m*3m) used for analyses.

Table 1. A sample Solar Radiation W/m^2 in the Winter Period

DATE Time	***10/12/2008***	***15/12/2008***	***19/12/2008***	***23/12/2008***	***25/12/2008***
8:00	**311**	**305**	**310**	**290**	**300**
10:00	**569**	**542**	**559**	**537**	**540**
12:00	**990**	**963**	**980**	**950**	**954**
14:00	**605**	**590**	**602**	**573**	**579**
16:00	**326**	**310**	**321**	**288**	**302**
17:00	**209**	**194**	**201**	**172**	**182**

Table 2. A Sample Outside Temperatures ^oC in the Summer Period.

DATE	***Time and Temperature***		***Reading At noon time (mV)***	***Horizontal Solar Radiation (W/m^2)***	
10 August 2008	**6:00 pm**	**29.0** °C	**10 September 2008**	**6:00 pm**	**26.0** °C
	7:00 pm	**27.0** °C		**7:00 pm**	**22.0** °C
	8:00 pm	**26.0** °C		**8:00 pm**	**21** °C
	9:00 pm	**25** °C		**9:00 pm**	**21.0** °C
	10:00 pm	**25.0** °C		**10:00 pm**	**21.0** °C
	11:00 pm	**24.0** °C		**11:00 pm**	**20.0** °C
	12:00 pm	**24.0** °C		**12:00 pm**	**20.0** °C
15 August 2008	**6:00 pm**	**31.0** °C	**15 September 2008**	**6:00 pm**	**27.0** °C
	7:00 pm	**29.0** °C		**7:00 pm**	**26.0** °C
	8:00 pm	**28.0** °C		**8:00 pm**	**25.0** °C
	9:00 pm	**26** °C		**9:00 pm**	**24** °C
	10:00 pm	**26.0** °C		**10:00 pm**	**24.0** °C
	11:00 pm	**26.0** °C		**11:00 pm**	**24.0** °C
	12:00 pm	**25.0** °C		**12:00 pm**	**23.0** °C
25 August 2008	**6:00 pm**	**30.0** °C	**25 September 2008**	**6:00 pm**	**30.0** °C
	7:00 pm	**28.0** °C		**7:00 pm**	**27.0** °C
	8:00 pm	**26.0** °C		**8:00 pm**	**26.0** °C
	9:00 pm	**25** °C		**9:00 pm**	**25** °C
	10:00 pm	**25.0** °C		**10:00 pm**	**25.0** °C
	11:00 pm	**24.0** °C		**11:00 pm**	**24.0** °C
	12:00 pm	**24.0** °C		**12:00 pm**	**23.0** °C
31 August 2008	**6:00 pm**	**28.0** °C	**30 September 2008**	**6:00 pm**	**26** °C
	7:00 pm	**26.0** °C		**7:00 pm**	**26.0** °C
	8:00 pm	**24.0** °C		**8:00 pm**	**24.0** °C
	9:00 pm	**22** °C		**9:00 pm**	**22.0** °C
	10:00 pm	**22.0** °C		**10:00 pm**	**21** °C
	11:00 pm	**22.0** °C		**11:00 pm**	**21.0** °C
	12:00 pm	**21.0** °C		**12:00 pm**	**20.0** °C

Table 3. Saving Cost and Saving Percentage in the Summer Period.

Month	***Savings Cost (JD/month)***	***Savings Percentage***
May	*10.4*	*53%*
June	*11.06*	*57%*
July	*11.66*	*60%*
August	*07.8*	*40%*
September	*10.5*	*54%*
October	*12.3*	*63%*
Average	***10.6***	***54.5%***