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The concept of unnatural roof garden to reduce energy consumption and electricity bills for houses in Bahrain

Dr. Saad F. Al Nuaimi[1*]

1. Department of Civil engineering and Architecture, College of engineering, University of Bahrain, Isa town, Bahrain

* dr.alnuaimisaad@yahoo.com

Abstract

The green roof technology has become one of the most important techniques in present days to reduce energy consumption inside buildings especially in hot climates.

Bahraini residential roofs are usually constructed with precast concrete, which, alongside with natural plant needs (soil and irrigation) makes the natural roof garden technique difficult to implement.

This research will present a new option to reduce the energy consumption inside residential buildings in Bahrain. The new concept depends on using unnatural grass (turf) added on the concrete roofs for residential buildings in Bahrain.

A simulation computer program "e-QUEST" will be used as simulation tool; to calculate the energy consumption and energy costs for each case study.

The use of unnatural grass on the concrete roofs will reduce (150,321.6B.D = 414.88 Dollars) annually for the selected model and an annual energy consumption reduction of (68 kWh). The annual reduction in energy consumption for each square meter is (7.556 kWh). The maximum reduction for bills' energy consumption is verified in July, while the minimum reduction for bills' energy consumption is verified in January.

Keywords: Reduce energy, Energy costs, Energy consumption, Unnatural roof garden, Bahraini houses.

1. Introduction

Nowadays the increase in energy consumption is very important, because of the future shortage in fossil fuel energy and also global warming. Many studies refer to this research problem. Yalmis in his study (Yilmaz, 2007) said “The efficient use of energy has turn out to be a key issue for most energy policies, especially for Buildings as it is one of the highest energy consumers".

According to the data of US Energy Information Administration, the world energy usage has and will increase tremendously. (Srivastava-Modi, 2011)

Designing buildings which use less energy has become extremely important, and the ability to evaluate buildings before construction can save money in design changes.(Stoakes, 2009)

According to reports of energy consumption in Bahrain which have been done by the Bahrain Ministry of Electricity & Water (BMEW, 2005), the energy consumption in the Kingdom of Bahrain since 1998 has increased from 5773 GW to 10689 GW in 2007 as shown in (Figure 1) with an increasing rate of 7.5% in energy consumption every year as its shown in (Figure 2).

According to the published data by the Bahrain Ministry of Electricity & Water (BMEW, 2005), the residential buildings in Bahrain consumed 54.5% of the total energy use (Figure 3), with increasing rate of 7.5% in energy consumption every year.

For all previous studies this research discusses a new concept to reduce the energy consumption inside the residential buildings in Bahrain by using unnatural roof garden. This reduction in energy consumption will also reduce the electricity bills during the months and during the hall year.

2. Research Methodology:

The research will use the inductive research methodology through the experimental methodology, by choosing a computer model as one residential space case study in Bahrain. The research will use an efficient computer simulation program called eQuest program to find the results after which the results will be discussed in order to reach the final conclusions.

3. Previous Studies:

Many researches have been done on energy consumption in buildings; some of these studies are given bellow:

3.1 Issa Jaffal, Salah-Eddine and Rafik , 2012

The study of Issa and others finds many significative results, such us: green roofs are thermally beneficial for hot, temperate, and cold European climates. The study of green roof thermal model was coupled to a building simulation code, that studies the impact of a green roof on the overall roof temperature and heat flux. Green roofs reduce buildings energy demand and improve thermal comfort.

3.2 Kasera, ashish nayyar, dr. Dilip , 2012

The researchers found that space constraints have been reducing the applicability of green surfaces in various areas surrounding the building envelope. Consequently, planted roofs become the only promising and stabilizing choice in the present scenario. Good thermal protection can greatly reduce the high thermal loads responsible for affecting the comfort inside buildings during summer. Planted roofs contribute not only in reducing the thermal loads on the building's shell but also in reducing urban heat island effects in densely built areas with reduced natural environment. It has described the cooling energy potential of shade trees by reduction of the local ambient temperature.

3.3 Stoakes, 2009

Stoakes in his study found that the biggest part of energy consumption is used in the conditioning of buildings to provide internal thermal comfort. In residential buildings, almost 51% of the total energy consumption is used for conditioning. More efficient buildings can potentially have larger savings in energy and cost related conditioning.

3.4 Hudson, 2008

During the hot humid summer months; the air-conditioning represents a significant proportion of this consumption. Even if residents are the ones most interested in lowering their utility bills and having a fast payback period for the additional costs related to energy efficient practices.

3.5 Al-Homoud, 2005

The US Department of Energy cited represents the biggest share of air-conditioning in energy used to operate buildings. In average the American home, uses between 50–70% of energy for space heating and cooling. This percentage possibly will be higher in a place with more harsh climatic conditions and less energy efficient buildings.

3.6 Cheng et al., 2005

Cheng studies [9] shows that to reduce the cooling requirements we should strive for more energy efficient building envelope designs for walls, roof and windows, by limiting the amount of heat gain that comes into the building interior.

3.7 Al-Homoud, 2004

Al-Hamoud in his study approved that the large amount of energy used in buildings is for air-conditioning and ventilation systems and is directly related to the thermal load of the building. Heat transfers by conduction through walls and roofs components represent the majority of the thermal load of buildings. This load of air-conditioning can be reduced through many strategies; one of these is the proper design and selection of the components of building envelope.

3.8 Elhadidy et al., 2000

El-hadidy in his study submitted to the King Fahd University shows that the air conditioning consumes about 73% of total electricity in the residential sector.

3.9 Lam et al., 2005

Lam's study finds that the heat gain for any building envelope comes in three types: wall or roof conduction, window conduction, and solar heat through the windows.

Many researchers studied the problem of the energy consumption in buildings and focused on the building's design.

All previous studies proved that there is a relationship between green grass and the energy consumption of buildings, while there is no study about the unnatural grass and energy consumption. This research will study the savings on energy bills through the reduction of energy consumption in existing buildings by adding unnatural grass.

4. Research Hypothesis:

The research study tries to approve the hypothesis "The use of unnatural roof garden will reduce the energy consumption and electricity bills in residential buildings in Bahrain".

5. Research Hypothesis:

The research will use a virtual model located in Bahrain composed of an independent single room. The room has a cubic shape (3m X 3m X 3m) composed of the structural and construction materials common in residential buildings in Bahrain, specially the buildings which have been built by the ministry of housing (concrete blocks for walls, precast concrete for the roofs, aluminum window frame with flat glass and aluminum door). The internal thermal comfort zone will be fixed. The outside weather will be determined according to Bahrain weather file. The model is designed to fix the changing effects of different variables such as shape, materials, orientation and environment. In order to increase the thermal efficiency of concrete slabs, unnatural green materials were added to the existing concrete roof.

This research will be a first step to reduce the energy consumption inside buildings, and many other steps will come in future researches.

6. Green Roofs and Sustainability:

Green roofs are regarded as a sustainable technology that offers several benefits to the society. These benefits are: reduced energy demand for space conditioning, reduced storm-water runoff, expanded lifetime of roofing membranes as well as reduced urban heat island effect when implemented in entire neighborhoods. In general, green or vegetated roofs are specific roofing systems that support vegetation growth on rooftops (Tabares-Velasco 2011)

Several important field experimental studies of green roofs in North America have compared the thermal performance of green roofs for summer weather conditions. Average heat flux reduction through these roofs varied from 18% to 75% when green roof layers were installed. A large variation of heat flux reduction could be attributed to experimental setups, plant coverage, building design, and local weather conditions. Interestingly, field studies and the laboratory studies have found a significant reduction of heat flux from a green roof compared to a bare soil roof.

The green roof is one of the solutions that have a positive effect on the energy performance of buildings, providing a cooling effect in summer, along with a more efficient harnessing of the solar radiation due to the reflective properties found inside the foliage (Ouldboukhitine, 2011)

7. Unnatural Grass (Artificial Turf):

The concept of green roof normally refers to the use of natural grass however, in Bahrain; the use of natural over the existing roofs is not a good solution due to the nature of the precast concrete roof type normally used in residential buildings. In addition to that, the natural grass needs for irrigation will lead to water leakage problems. That is why the research will use unnatural roof garden instead of the natural grass.

The research will use the artificial turf or unnatural grass with the following specification (Neda, 2009) and (www.diytrade, 2012) over the existing precast concrete roof:

1- Model Number: AJ-QDS 36-4

2- Turf conductivity = 0.242833913 Btu/h.ft-F.

3- Turf thickness = 0.12 ft

4- Turf density = 60.0 lb/ft cubic

5- Turf specific heat = 40613000 Btu/lb-F.

8. Electricity Tariff:

According to the published reports by the electricity and water authorities in Bahrain, there is a limited tariff for electricity that can be found on the ministry website. This tariff has been determined for each sector in Bahrain (http://www.dynamic-ews.com/Tariffs/Electricity%20Tariffs/Bahrain.pdf).

The residential (domestic) tariff is depending on use quantity, as shown in table 1. For the research study the tariff unit will be calculated as 3 Fils/kWh for all units as a minimum price. (1 Bahraini dinar = 2.67 Dollars).

9. Study Model: Built Computer Model:

The study will simulate the thermal performance of the precast concrete used to construct the roof, adding the unnatural garden for the test model.

The building considered in the study is one small single room in a residential house in Bahrain as shown in figure 4 (view taken from eQuest energy simulation tool). The room consists of two plain walls, one wall with window and the other wall with a door.

The walls are built with the typical material used in Bahrain: "0.2 meter hollow block". The is ceiling made of concrete slab with a gypsum interior finishing. The test case study building is located under Bahrain weather conditions with a total floor area of (9 m2).

The building model consists of one zone. Since the building is a residential test model, the operation schedule is made for 24 hours a day and 7 days per a week. The internal temperature for the building is considered to be 24˚C, which is considered as the appropriate temperature for human comfort. Hourly weather data of Bahrain for the years from 1998 to 2010 is used as the weather file required by the simulation program eQuest. The weather file contains hourly data for dry bulb temperature, wet bulb temperature, wind velocity, cloudiness, direct radiation and diffuse radiation. The values of physical parameters are to be used as base-case values shown in table 2.

In order to investigate the effect of unnatural grass (artificial turf) on energy consumption, the model will be tested using eQuest 3.64 energy simulation program. The simulation was performed using weather data file from the years 1998 to 2010, for Al-hidd in Al-Muharaq Bahrain (TMY2), from the web site Weather Analytics Inc. "Precision, On-site Weather Data for Energy Use Profiling, Modeling and Management" (Inc, 2012) http://www.wxaglobal.com/GetWeatherData.html. The weather file used in eQuest consists of a parameters group as describe in Table 3.

10. The Results:

After input the previous data and run the eQuest simulation program, many new results appear. The program finds two groups of results for two different cases; the first case refers to the existing concrete roof with water proof normally used in residential buildings, while the second case refers to the existing concrete roof with water proof and adding the unnatural grass or artificial turf.

Figure 5 is showing the monthly energy consumption for the existing concrete roof by using eQuest program. Figure 6 is showing the monthly energy consumption for the existing concrete roof and unnatural grass by using eQuest program. Figure 7 is showing total annual electric Consumption for the existing concrete roof and with the unnatural grass (artificial turf) by using eQuest program. Figure 8 is showing total annual electric Consumption for the existing concrete roof and with the unnatural grass (artificial turf) by using eQuest program.

11. Result Analysis:

According to the previous results, table 4 shows the monthly and annual energy consumption for the two cases. There are reductions in the overall monthly energy consumption and in the annual energy consumption, used for the air-conditioning, because of the use of the new layer of unnatural grass (artificial turf).

The table 5 is showing the differences in energy consumption between the existing concrete roof and the existing concrete roof with the unnatural grass. While the figure 9 shows these differences due to the addition of unnatural grass.

The results show that there are monthly differences between the energy consumption when the roof is with or without unnatural grass. The monthly reduction on energy consumption by (kW.h) if calculated during 24 hours (all-day), multiply 30 days for the months (April, June, September and November) or multiply 31 days for the months (January, March, May, July, August, October, and December) or multiply 28 days for February as shown in figure 10. The total annual reduction will be (150321.6 Bahraini Fils) for the area of the single room which is 9 square meter. That means, for each square meter (16702.4 Bahraini Fils) will be reduced annually if the unnatural roof garden will be used over the houses, as shown in table 6.

12. Conclusion:

The research tries to discuss a new concept: the use of unnatural roof garden to find a new solution for reducing the annual energy consumption and the bills for air conditioning inside the residential buildings in Bahrain.

According to this study, by using Unnatural grass (Artificial or turf) for existing residential buildings in Bahrain, the research finds the following conclusions:

1- Using the unnatural grass will reduce annually (150,321.6B.D = 414.88 Dollars).

2- The annual reduction in energy by using unnatural roof garden for the study model is (68 kWh) and annually reduction in energy consumption for each square meter will be (7.556 kWh).

3- The maximum reduction for bills' energy consumption was in July. The bills' reduction for each square meter hourly is 30.3 Bahraini Fils = 0.81 dollar, and monthly 22543. 2 Bahraini Fils = 60, 19 Dollars.

4- The minimum reduction for bills' energy consumption was in January. The bills' reduction for each square meter hourly is 3.9 Bahraini Fils = 0.104 dollar, and monthly 322.4 Bahraini Fils = 8, 61 Dollars.

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Dr. Saad F. Al Nuaimi/ Assistant professor/ Department of civil engineering and Architecture

University of Bahrain, dr.alnuaimisaad@yahoo.com, 00973 36668970

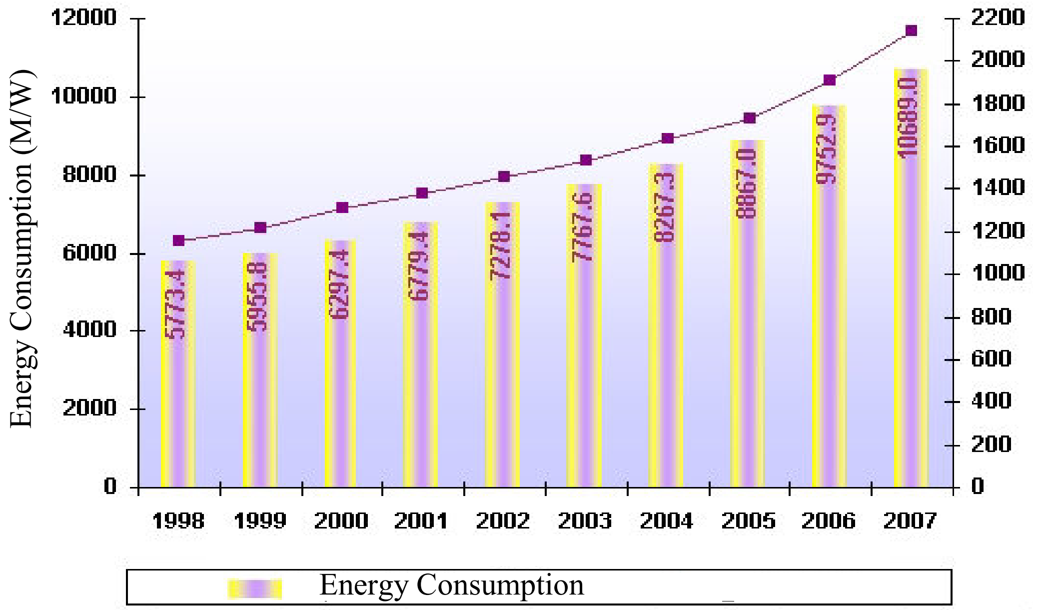

Figure 1: Energy consumption in the kingdom of Bahrain for ten years (BMEW, 2005)

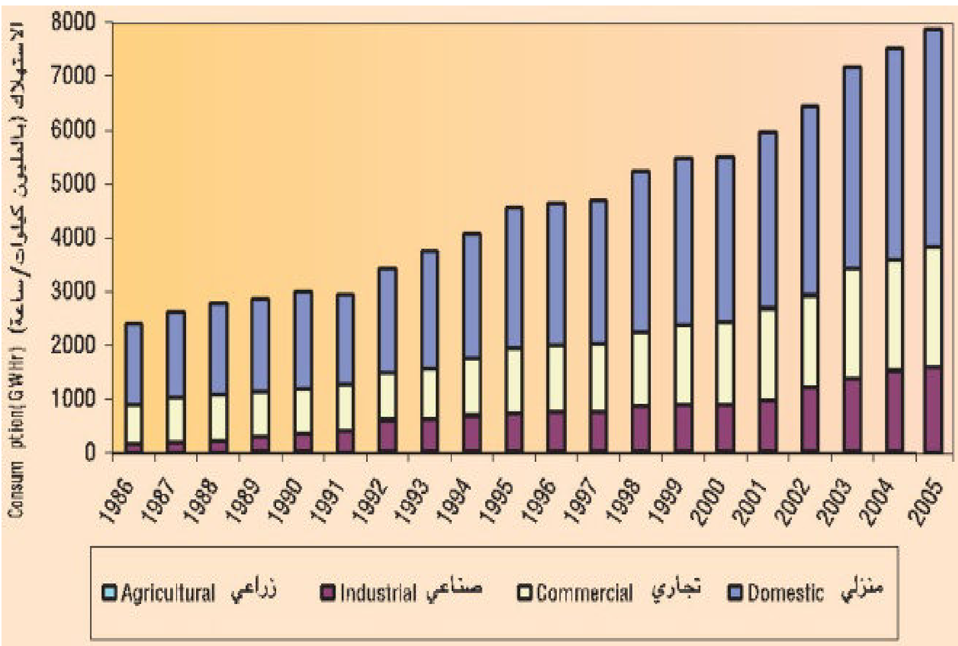

Figure 2: Sectorial Consumption of Electricity in Bahrain for twenty years (BMEW, 2005)

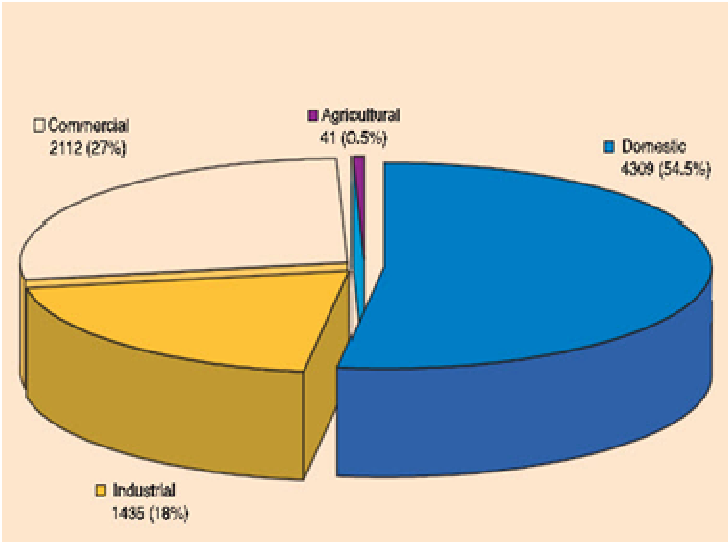

Figure 3: Sectorial Consumption of Electricity in Bahrain (BMEW, 2005)

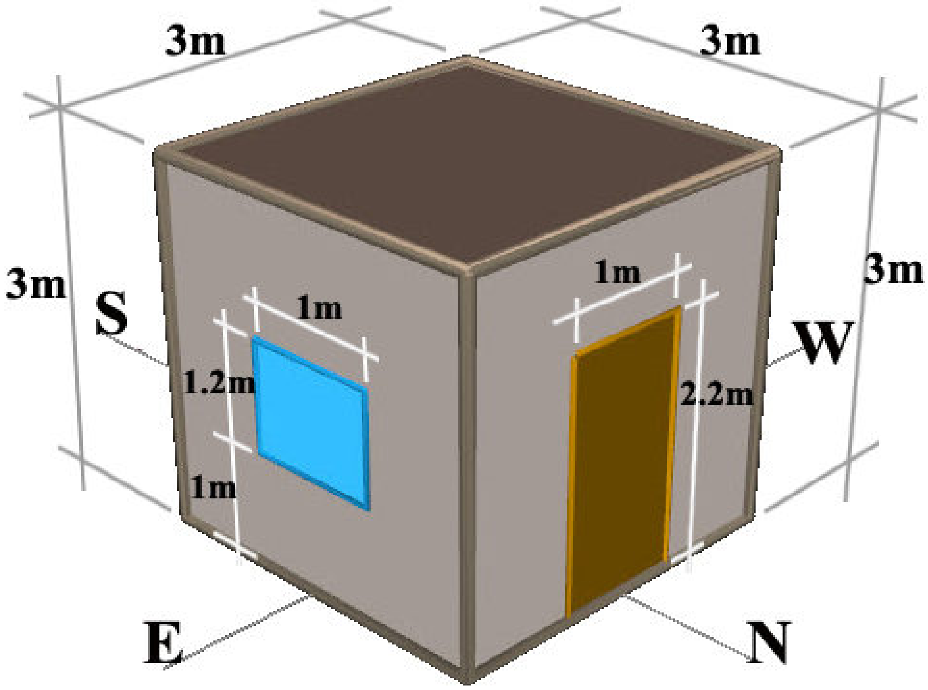

Figure 4: Shape and dimensions of experimental room the case study

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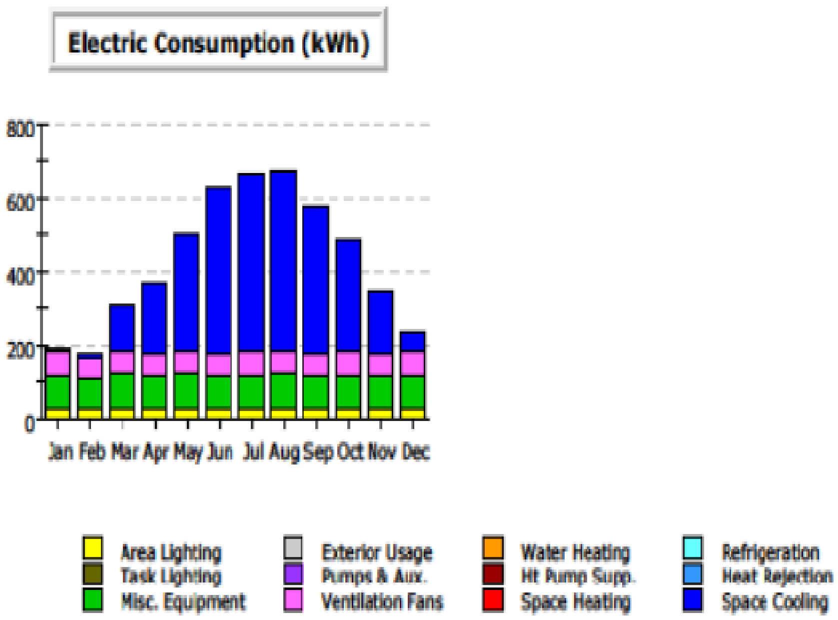

Electric Consumption (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	6.9	11.6	117.8	195.9	316.5	444.6	483.8	485.1	401.1	299.5	165.3	55.9	2,984.2
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	67.6	61.1	67.6	65.4	67.6	65.4	67.6	67.6	65.4	67.6	65.4	67.6	795.9
Pumps & Aux.	-	0.1	-	-	-	-	-	-	-	-	-	-	0.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	84.1	77.5	89.0	82.5	87.4	85.7	84.2	89.0	82.4	85.8	82.4	84.1	1,014.2
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	31.0	28.2	31.5	30.1	31.4	30.5	31.0	31.5	30.1	31.2	30.1	31.0	367.5
Total	189.7	178.4	306.0	373.9	502.9	626.1	666.6	673.2	579.0	484.1	343.3	238.7	5,161.9

Figure 5: Monthly energy consumption for the existing concrete roof by using eQuest program.

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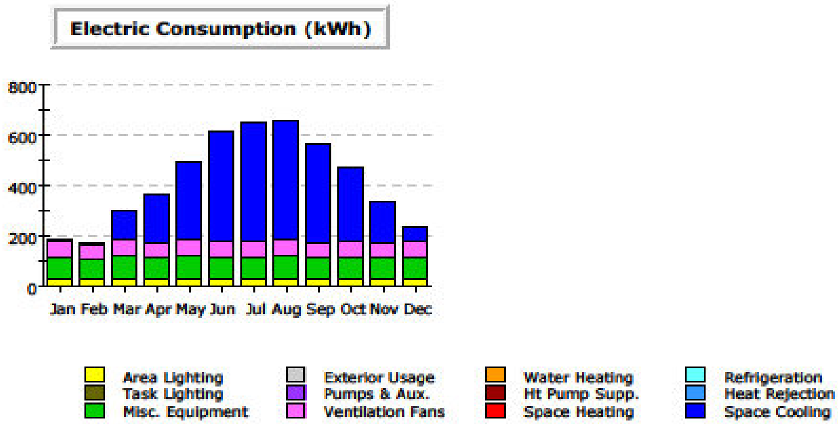
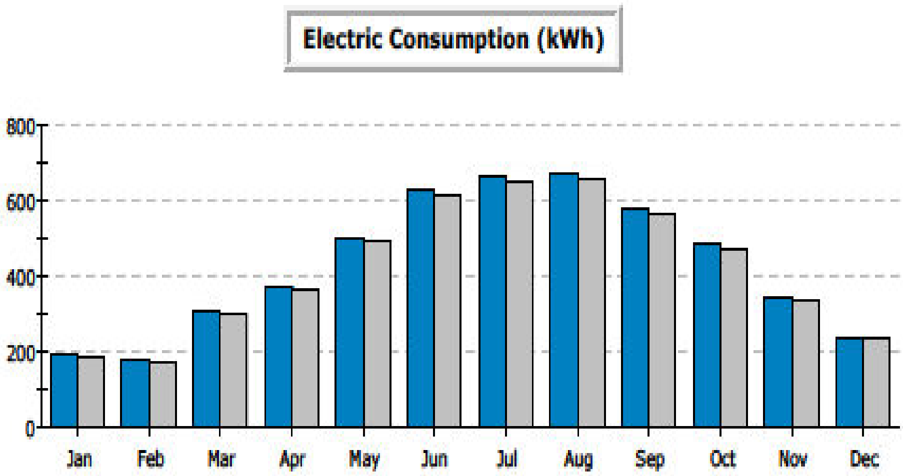


Electric Consumption (kWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	5.6	9.3	114.2	190.3	308.4	435.3	473.7	475.5	393.4	293.2	162.1	54.5	2,915.7
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	63.7	57.6	63.7	61.7	63.7	61.7	63.7	63.7	61.7	63.7	61.7	63.7	750.4
Pumps & Aux.	-	0.1	-	-	-	-	-	-	-	-	-	-	0.1
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	84.1	77.5	89.0	82.5	87.4	85.7	84.2	89.0	82.4	85.8	82.4	84.1	1,014.2
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	31.0	28.2	31.5	30.1	31.4	30.5	31.0	31.5	30.1	31.2	30.1	31.0	367.5
Total	184.5	172.6	298.5	364.6	490.9	613.1	652.6	659.8	567.7	474.0	336.3	233.4	5,047.9

Figure 6: Monthly energy consumption for the existing concrete roof and unnatural grass by using eQuest program.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Run 1.	189.7	178.4	306.0	373.9	502.9	626.1	666.6	673.2	579.0	484.1	343.3	238.7	5,161.9
Run 2.	184.5	172.6	298.5	364.6	490.9	613.1	652.6	659.8	567.7	474.0	336.3	233.4	5,047.9
Run 3.													
Run 4.													
Run 5.													

1. saad - Baseline Design (10/31/12 @ 19:33)
2. saad - 12 (10/31/12 @ 19:33)

Figure 7: Total annual electric Consumption for the existing concrete roof and with the unnatural grass (artificial turf) by using eQuest program.

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Annual Electric Energy by Enduse (pg 1 of 4)

Annual Energy USE (kWh)	Ambient Lights	Task Lights	Misc Equip	Space Heating	Space Cooling	Heat Reject	Pumps & Aux	Vent Fans	Dom Ht Wtr	Exterior Usage	Total
0 Base Design	368	0	1,014	0	2,984	0	0	796	0	0	5,162
12 0+artificial grass	368	0	1,014	0	2,916	0	0	750	0	0	5,048

Figure 8: Total annual electric Consumption for the existing concrete roof and with the unnatural grass (artificial turf) by using eQuest program.

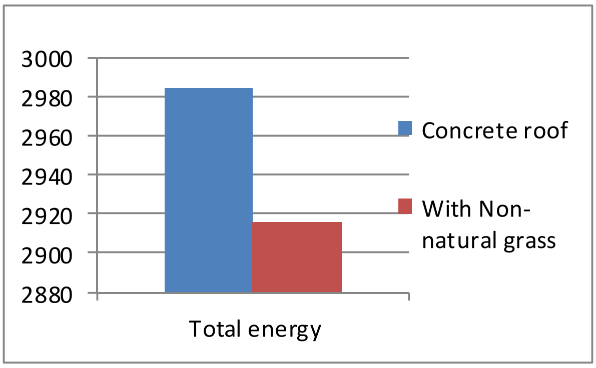

Figure 9: differences in energy consumption kW.h caused by the unnatural grass.

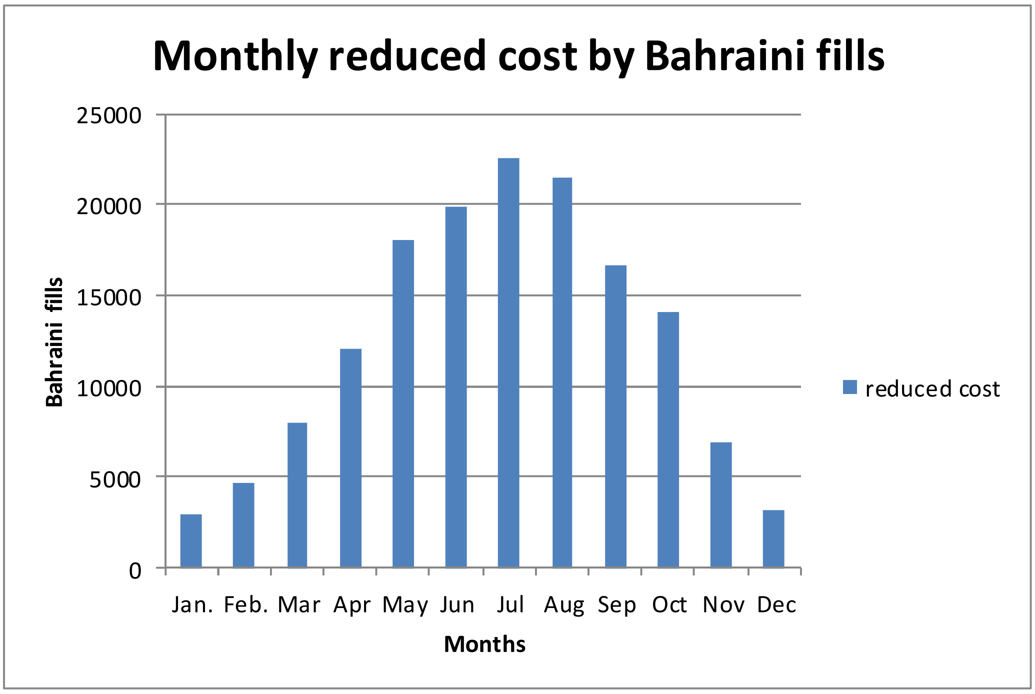

Figure 10: monthly and annually reduced bills by using unnatural roof garden on existing residential buildings.

Table 1: Bahrain electricity tariffs for domestic and non-domestic using. (http://www.dynamic-ews.com/Tariffs/Electricity%20Tariffs/Bahrain.pdf)

Slab in kWh	Domestics Tariff in Fils/kWh	Non-domestic Tariff in Fils/kWh
1 to 3000	3	16
3001-5000	9	16
Over 5000	16	16

Table 2: Characteristics and description for the case study

Characteristics	Description of the case study
Plan View	Square
Number of Floors	1floor
Floor to Floor Height	3m
Floor Area	9 m2
Total Area of Opaque Walls	32.6 m2
Total Area of Glazing	1.2 m2
Total Area of doors	2.2 m2
Interior Temperature, Tj	24 (˚C)
Occupancy density	25 (m2/person)

Table 3: weather data file descriptions (Inc, 2012)

Name	Description
cDateLT	Date and hour string in Local Time [YYYY-MM-DD-HH].
The year(YYYY)	Is set to "2012".
Ta_C	Air temperature [Celsius]
Td_C	Dew point temperature [Celsius]
Ta_F	Air temperature [Fahrenheit]
Td_F	Dew point temperature [Fahrenheit]
Rh_Pct	Relative humidity [Percent]
Pa_Mb	Surface air pressure [Millibars]
ExtGlobHorz_WpSqM	Extra-terrestrial solar radiation [Watt hours per square meter]
ExtDirNorm_WpSqM	Extra-terrestrial direct normal solar radiation [Watt hours per square meter]
GlobHorz_WpSqM	Global horizontal solar radiation [Watt hours per square meter]
DirNorm_WpSqM	Direct normal solar radiation [Watt hours per square meter]
DifHorz_WpSqM	Diffuse horizontal solar radiation [Watt hours per square meter]
WindDir_DEG	Direction whence wind is blowing [Degrees]
WindSpd_MpS	Wind speed [Meters per second]
WindSpd_KTS	Wind speed [Knots]
LiqEquivPcp_MM	Liquid-equivalent precip [Millimeters]
LiqEquivPcp_IN	Liquid-equivalent precip [Inches]

Table 4: Monthly and annual energy consumption by (kW. h) for the existing concrete roof and the existing concrete roof with the unnatural grass.

Months / Energy consumption	Jan.	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Ann.
Concrete roof	6.9	11.6	117.8	195.9	316.5	444.6	483.8	485.1	401.1	299.5	165.3	55.9	2984
With unnatural grass	5.6	9.3	114.2	190.3	308.4	435.4	473.7	475.5	393.4	293.2	162.1	54.5	2916

Table 5: The differences between the existing concrete roof and the existing concrete roof with the unnatural grass.

Roof type / Energy consumptions	Concrete roof	With Unnatural grass
Annual energy	2984	2916

Table 6: monthly and annual reduced energy consumption by (kW. h) and the costs by (Bahraini Fils) if using concrete roof with the unnatural grass.

Months / Bahraini Fils	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec	**Annual**
Reduced energy	1.3	2.3	3.6	5.6	8.1	9.2	10.1	9.6	7.7	6.3	3.2	1.4	**68.4**
Bahraini Fils reduce	3.9	6.9	10.8	16.8	24.3	27.6	30.3	28.8	23.1	18.9	9.6	4.2	**205.2**
Reduced per a day (x 24 h)	93.6	165.6	259.2	403.2	583.2	662.4	727.2	691.2	554.4	453.6	230.4	100.8	**4924.8**
Reduced per month (x 28) (x 30) or (x 31) days	2901.6	4636.8	8035.2	12096	18079.2	19872	22543.2	21427.2	16632	14061.6	6912	3124.8	**150321.6**
Monthly reduced for each square meter	322.4	515.2	892.8	1344	2008.8	2208	2504.8	2380.8	1848	1562.4	768	347.2	**16702.4**