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Azabany, Azad, Khan, Khalid, Ahmed, Waqar and Shah, Mahmood Hussain

Available Online at http://www.journalajst.com

ASIAN JOURNAL OF SCIENCE AND TECHNOLOGY

ISSN: 0976-3376

Asian Journal of Science and Technology
Vol. 5, Issue 9, pp. 541-545, September, 2014

RESEARCH ARTICLE

ENERGY ANALYSIS FOR REPLACING FOSSIL FUEL ENERGY SOURCE OF ELECTRICITY WITH SOLAR CELLS IN THE UK AND KURDISTAN, IRAQ

[1]Azad Azabany, [2]Khalid Khan, [3*]Waqar Ahmed and [1]Mahmood H Shah

[1]Lancashire Business School, University of Central Lancashire, Preston PR1 2HE, UK
[2]School of Forensic and Investigative Sciences, University of Central Lancashire, Preston PR1 2HE, UK
[3]School of Medicine and Dentistry, University of Central Lancashire, Preston PR1 2HE, UK

ARTICLE INFO

Article History:
Received 03rd June, 2014
Received in revised form
08th July, 2014
Accepted 29th August, 2014
Published online 22nd September, 2014

Key words:

Energy Management,
Cost, Environment,
Solar Cells,
Iraq, UK.

ABSTRACT

Energy is a vital resource required for the operation of any business. Currently, the vast majority of businesses use electricity derived for non-renewable fossil fuels, which are expected to run out at its current rate of expenditure and causing substantial environmental damage threatening the future generations. In the UK if the current energy source used by small and medium enterprises (SME's) could be replaced by solar energy then damage to the environment can be prevented and reduce costs as solar cells become more efficient. Solar cells involve harnessing the energy from the sun to generate electricity. In this study a methodology has been developed to compare a model micro-business in Manchester, UK and Kurdistan, Iraq. The comparison shows quantatively that even though Kurdistan, Iraq is abundant in oil and gas its climatic conditions favour the implementation of solar cells. Therefore, it is more feasible to replace the existing non-renewable fossil fuel sources with solar cells in Iraq due to greater solar radiation striking the earth's surface. Our research suggests that solar cells can replace a reasonable amount of the energy requirements even in Manchester, UK and a much higher proportion in Kurdistan, Iraq. Using existing 20% efficient silicon solar cells we can replace 28% and 88% of the energy requirements of the micro business in UK and Kurdistan, Iraq respectively.

INTRODUCTION

There is a worldwide energy crisis due to lack of supply in numerous parts of the world, the damaging effect on the environment and increasing price volatility. The Middle East represents 5% of the world's population but has about 66% of world's oil reserves and 43% of world gas reserves, (Petroleum, 2011; Ahmad and Babar, 2013 and Farzaneh *et al*., 2013). Even though some of Middle Eastern countries are rich, this windfall wealth is unevenly distributed and does not always lead to a widespread economic development. The USA accounts for 5% of the world's population and is responsible for about 25% of the world energy consumption and related greenhouse gas emissions (Le Quéré *et al*., 2009). The world demand for oil and gas is increasing significantly each year due to rising demands from countries such as India and China where industrialization and the demand for consumer products is escalating at an unprecedented pace (Billon and Khatib, 2004). The country is highly dependent on imports of oil and natural gas. This means that the consumption of non-renewable energy is still rising. If energy derived from fossil fuel sources can be replaced by solar energy then environmental damage can be reduced and energy can be generated at source without the need for an extensive infrastructure development for transporting oil, gas and electricity. In this paper, the feasibility of replacing fossil fuels sources of electricity with solar energy from the sun has been investigated. Energy analysis has been carried for a micro-business in the UK, which could be duplicated in Kurdistan, Iraq. Analysis of the available solar energy for such a business in both the U.K and Kurdistan, Iraq has been carried out together with an estimate of the reductions in harmful carbon emissions. The energy utilized by all the tools and components used in business operation have also been analyzed to determine the maximum usage points in the business.

***Corresponding author: Waqar Ahmed,** *School of Medicine and Dentistry, University of Central Lancashire, Preston PR1 2HE, UK*

MATERIALS AND METHODS

The amount of electricity consumed from a non-renewable source was measured in a Gents Hairdressing Salon chosen as a business unit to test the system and develop protocols. These can be applied to other small business units. The first step was to understand and evaluate the tools and units that consumed electricity inside the salon. The electricity consumed was obtained from the electricity meter readings. The electricity input was divided into various components, tools and devices employed in the business. An analysis of the usage of each tool and device within the business was determined by measuring the utilization time for each tool. The peak and average energy use of this salon was analyzed. The energy consumed by each tool and other units such as the bulbs, shower rate, kettle, music centre, hair dryer, large clipper, and small clipper was measured. The timer was started as soon as the stylist picked up the clipper from the rack. A stopwatch on an i-phone device was used to measure the time. It is important to note that styling is a creative and individualistic activity. During clipper use visual examination of the hair takes place and brief conversations, which are sources of errors, which are unavoidable since business takes precedence. The timer was kept on until the stylist put it back on the rack. The time used was then noted. Several factors keep the clipper for longer period of time such as thicker and longer hair. This tool was mainly used for shaving back and side of the head for hair cutting or shaving all the head only with the clipper. The same procedure was repeated for the small and large clippers used for trimming hair. The hair dryer consumes a relatively large amount of electricity. The measurement methodology was the same as large and small clipper. The timer started as the hair dryer is picked up and then stopped when it is put back on the rack. The timing for the shower unit was slightly modified. The timer was started as soon as the client sat on the chair. In between the shower was used, conditioner was applied and the hair dried. The timer was turned off when the client left the chair. Calculation of the amount of electricity consumed was done using the total time measured and the power rating of the shower. Other items using electricity included: bulbs including 100W and 60W, kettle for coffee and tea, music centre, heater and computer. The music centre, lighting and computer were on for the whole opening business amounting to 10 hours a day for six days a week. Hence the calculation of the electricity consumption was straight forward amounting to 3,120 hours per annum. The kettle was used several times a day and its usage time was measured. Heating was switched for an average of six hours per day. For each tool and component the energy consumed was calculated using:

$$Energy\ consumed = power\ rating \times time$$

$$E = P \times t$$

where the energy consumed is given in Joules, power rating in Watts and time in seconds.

RESULTS AND DISCUSSION

Analysis of Electricity Consumption: The power used by the tools in cutting hair is given table 1. This was used to determine localized electricity cost for each tool used in a hair salon.

Table 1. Electrical devices, time utilized, energy used and cost

Equipment	Rating (kW)	Time (hr)	Energy (kWh)	Cost (£)
Large clipper	0.01	1.27	0.0127	0.001905
Small clipper	0.005	0.78	0.0039	0.000585
Hair dryer	2	0.45	0.9	0.135
Shower	7.5	0.24	1.8	0.27
Other uses				
Lights	0.06 x 20	10	12	1.8
Heating	2	6	12	1.8
Radio	0.2	10	2	0.3
Computer	0.1	10	1	0.15
Kettle	2	0.5	1	0.15
Total	15.02	39.24	30.72	4.61

Figure 1 shows the electrical consumption for various items.

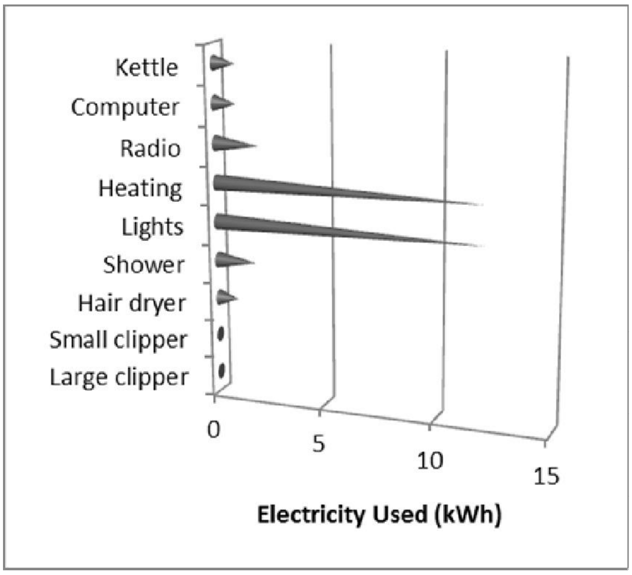

Figure 1. Proportion of electrical energy used by the various tools and appliances

The cost of electricity [7] has been calculated using the formula

$$C = E \times UP$$

where E is the energy in kWh, P is the power in Watts, t is the time in hours, C is the cost in £ and UP is the unit price (£0.15). Hence, the daily cost has been calculated to be £4.61.

Energy consumed and costs

The energy used and associated costs are shown in table 2.

Table 2. Monthly and annual energy utilization and costs

Month	Days open	Monthly energy used (kWh)	Calculated Monthly energy used (£)	Actual Monthly Electricity bill (£) inclusive VAT
Jan	25	768	115.20	79.44
Feb	25	768	115.20	90.96
Mar	27	829	124.35	106.08
Apr	24	737	110.55	78.00
May	27	829	124.35	88.08
Jun	26	799	119.85	96.96
Jul	26	799	119.85	109.20
Aug	26	799	119.85	98.40
Sep	24	737	110.55	96.48
Oct	27	829	124.35	99.36
Nov	27	829	124.35	126.00
Dec	23	707	106.05	136.32
Total	307	9430	1414.50	1205.28

The salon opened 307 days in 2012 using 9,430 kWh of electrical energy, hence the monthly cost of electricity was calculated to be £1414.50 and the actual electric bill was £1205.28. The difference between the theoretical and actual value was £1414.50 – £1205.28 = £209.22 annually. Hence the daily difference between the theoretical and the actual electrical energy used was about £0.68 per day. As a percentage of the daily rate the amount can be calculated as

$$\%\ difference = \frac{0.68}{4.61} \times 100 = 14.75\%$$

The reasons for the discrepancy between actual and calculated values will be discussed later. The efficiency of solar cells has been increasing as new materials and architectures have been developed. One of the major objectives of this project is to examine the feasibility of replacing electricity generated from non-renewable fossil fuels with solar cells. A number of factors need to be considered and effect how much electricity is generated from solar panels on the roof. These include the size, number of panels, their power rating, position on the roof, and hours of daylight. Standard production solar panels based on silicon solar cells generate 1000W/m^2 with an efficiency of about 15-20%; hence a 1m^2 panel produces about 150-200W in good sunlight conditions and less in cloudy dull conditions. The efficiencies of commercial solar are expected to rise because research has already produced higher efficiency solar cells. In the past few years the adaption of solar panels widely has increased significantly due for several reasons (Outlook, 2010; Lenzen *et al*., 2006 and Perez *et al*., 2011):

i) The development of China as a world manufacturing base has made the cost of solar cells much more affordable.
ii) Improvements in efficiency has also made it feasible to consider the replacement of non-renewable sources
iii) Technological developments have also made solar panels more reliable and easily installed on roofs of buildings
iv) The government has introduced subsidised investments and incentives for homeowners to install solar panels on their roofs.

Factors such as efficiency, cost and reliability have meant that there has been a rapid rise in adoption of solar energy to replace non-renewable fossil fuel source. There has been an exponential rise in the adoption of the technology in the USA (Zweibel, 2010). To see the relationship between the numbers of days the shop opens with the number of customers served and the amount of energy consumption see table 3.

Table 3. Monthly energy utilization, customers and days open

Month	No of days open	Units consumed (kWh)	No of customers served
Jan	25	331	630
Feb	25	379	620
Mar	27	442	645
April	24	325	585
May	27	367	595
June	26	404	725
July	26	455	755
Aug	26	410	760
Sept	24	402	775
Oct	27	414	745
Nov	27	525	770
Dec	23	568	855
Total	307	5,022	8,460

Table 4. Normalized energy utilization, customers and days open

Month	No of days open	Units consumed	No of customers served
Jan	0.98	0.79	0.89
Feb	0.98	0.91	0.88
Mar	1.06	1.06	0.91
April	0.94	0.78	0.83
May	1.06	0.88	0.84
June	1.02	0.97	1.03
July	1.02	1.09	1.07
Aug	1.02	0.98	1.08
Sept	0.94	0.96	1.10
Oct	1.06	0.99	1.06
Nov	1.06	1.25	1.09
Dec	0.90	1.36	1.21

The relationship between the number of days open, units of electricity consumed and customers served was explored by normalizing the data with the mean values see table 4 and figure 2.

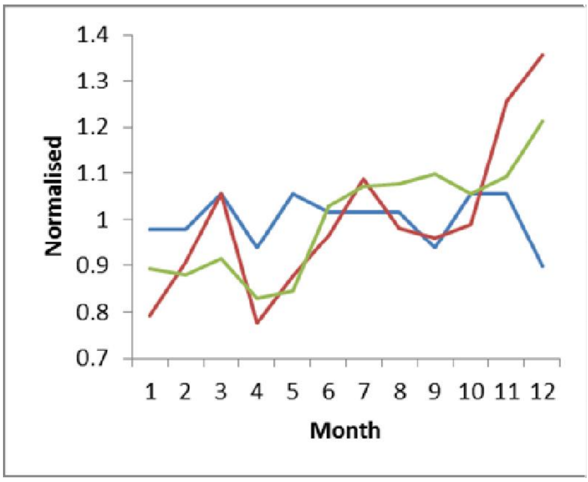

Figure 2. Normalized values of days salon is open (blue line), electricity used (red line) and customers (green)

There does not appear to be a relationship between the number of days the salon is open and the amount of electricity consumed and customers served. However, there may be a relationship between the amount of electricity consumed and the number of customers served see figure 3.

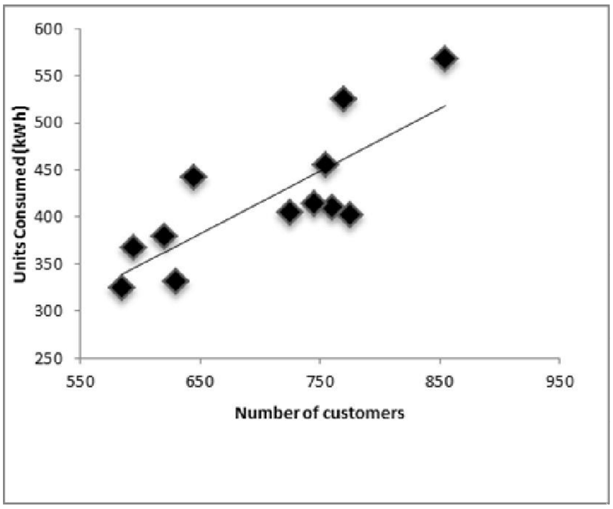

Figure 3. Linear relationship between number of customers and electrical units consumed

Figure 3 indicated that there is a weak positive correlation between the number of customers and the amount of electricity used. Hairstyles are individual choices and various styles are offered and customer preferences need to be considered. In addition, the state of the hair when the customer visits the salon for example there is variation in the length of hair and extent of restyling also differs. These factors result in variations in the time and tool required to cut and style hair according to customer satisfaction.

Relationship between energy consumption and CO_2 generated

Let us consider how much CO_2 can be prevented from getting into the atmosphere and how it will impact the environment. It has been calculated that in the USA 1KWh electricity generates an equivalent of 0.58kg of CO_2 compared to the UK figure of 0.43 kg. It is informative to investigate how much CO_2 is generated by a small hairdressing salon. This is calculated using the data in table 5.

Table 5. Units of electricity consumed and the carbon dioxide generated

Month	Units consumed (kWh)	UK Carbon dioxide produced (kg)
Jan	331	142.33
Feb	379	162.97
Mar	442	190.06
Apr	325	139.75
May	367	157.81
Jun	404	173.72
Jul	455	195.65
Aug	410	176.3
Sep	402	172.86
Oct	414	178.02
Nov	525	225.75
Dec	568	244.24
Total	5022	2159.46

The annual consumption of electricity was 5022 kWh, which can be equated to the amount of CO_2 released into the atmosphere, which equates to 2159.46kg.

Feasibility of replacing fossil fuels with existing silicon solar panels

By replacing non-renewable source with solar panels we can prevent it from being released into the atmosphere to cause global warming and other environmental disasters. With millions of small businesses exist worldwide this will have a significant long-term impact. Solar cells rely on light for their mode operation it is useful to compare UK with Kurdistan, Iraq.

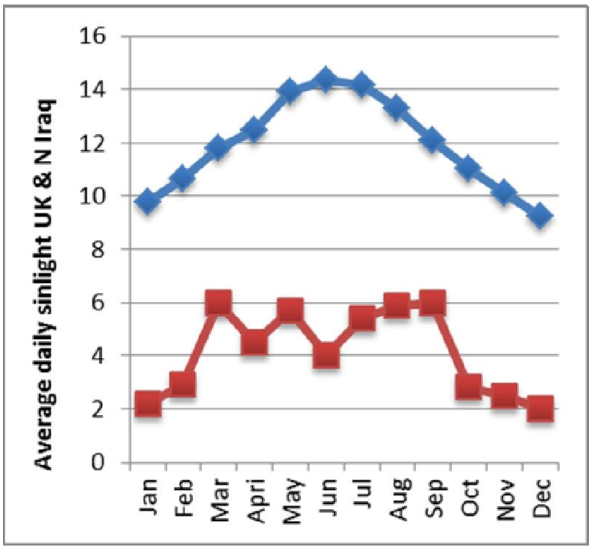

Figure 4. Shows a comparison between average daily sunshine in Kurdistan, Iraq compared to Manchester, UK in 2012

In 2012 the figures for daylight hours are shown in Figures 4 and in the UK in the winter the average amount of sunlight per day is about 2 hours equating to about 60 hours per month whereas in the spring, autumn and summer it is about 5 hours, which is about 150 hours per month (Candelise *et al*., 2010). When this compared to Kurdistan, Iraq the figure are 10 hours and 14 hours respectively per day. Hence, it not surprising that the weather conditions in Kurdistan, Iraq are more conducive to solar cell technology than the UK.

The expected electricity generated using solar panels can be calculated as follows:

$$Electricity = A \times 1000 \times \xi \times t$$

A is the area of solar panels, ξ is the efficiency and t is the

hours of sunlight to give the electricity generated in kWh per day. Considering the Grooms Gents Hairdressing Salon and we can calculate the amount of electricity that can be generated daily in UK and Iraq. The physical dimensions of the roof are 6 x 2 = 12 m^2 and about 50% of it is available for installation of silicon solar cells. Hence, an area of 6m^2 is this available for solar cell installation. The amount of electricity generated in a typical day UK is

Electricity (UK) = 6 x 1000 x 0.2 x 4 = 4,800 Wh/day = 4.8 kWh/day

The efficiency was assumed to be about 20% with day light of 4 hours typical an average in the UK in 2012 and the amount of electricity generated per day would be 4.8 kWh/day. Compared with Kurdistan, Iraq the calculation involves longer hours of daily sunlight and the intensity of sun is also much higher hence repeating the calculation gives

Electricity (N. Iraq) = 6 x 1000 x 0.2 x 12 = 14,400 Wh/day = 14.4 kWh/day

In Kurdistan, Iraq the amount of electricity generated for an equivalent business unit using the same solar cells 14.4 kWh/day electricity can be compared to the UK value of 4.8 kWh//day due to better weather conditions and therefore use of solar energy is much more attractive. This is 3 times more electricity generated in Kurdistan, Iraq compared to the UK making it more attractive as an environmentally friendly technology solution for energy production.

Table 6. Comparison between the Manchester, UK and Kurdistan, Iraq for 20% efficient solar cells and corresponding amount of reduction in CO_2

Silicon Solar cell efficiency (%)	UK (kWh)	Iraq (kWh)
20	4.8	14.4
Annual (307 days)		
20	1474	4421
Annual CO_2 reduction (kg)		
20	634	3227

Clearly calculations for the replacement of fossil fuels with solar cells show that the carbon emission will be decreased and reduce damage to the atmosphere. The benefits in Iraq would be much greater due to more sunlight and a about 5 times the reduction in CO_2 emissions can be achieved in Kurdistan, Iraq compared to UK. This is also applicable to other countries in the Middle East. For the UK we calculate the percentage of electricity generated from 20% efficient solar cells compared to fossil fuels to be as follows:

$$\%E\,(replaced) = \frac{E\,(solar)}{E(fossil)} \times 100$$

$$= \frac{1474}{5022} \times 100 = 29\%$$

However, for the same business in Kurdistan, Iraq with 20% efficient silicon solar cells and longer day light hours we can calculate the percentage of electricity needs that can be replaced with solar cells.

Table 7. Comparison of the percentage of current electricity requirements that can be replaced with solar energy using with silicon solar cells

Solar cell	Percentage of the energy requirements replaced with solar in the UK	Percentage of the energy requirements replaced with solar in Kurdistan, Iraq
Silicon solar cells (20%)	29	88

The calculations above using the solar panel with efficiency of 20% can replace only 29% of the total electricity required to run Groom Gents Hairdressing salon in the U.K. The replacement of fossil fuels with solar cells will also reduce the carbon emission into the atmosphere and reduce damage to the environment. However, in Kurdistan, Iraq due to longer daily and annual daylight hours we can replace 88% of the energy needs with silicon solar cells.

Conclusions

A methodology to compare a micro-business in the UK and Kurdistan, Iraq for energy utilization has been proposed. Kurdistan, Iraq is abundant in oil and gas however its conditions are highly favourable for implementing solar energy compared to UK. A proportion of fossil fuel sources can be replaced with silicon solar cells. For existing solar cells we can replace 29% and 88% of the energy requirements of the micro business in the UK and Kurdistan, Iraq respectively. The impact of fossil fuels on the environment in terms of carbon emissions could be reduced dramatically when summed over all such micro-businesses within the countries. Some of the differences in the actual electrical consumption of the micro-business and those calculated can be accounted for by using a lower unit price tariff comparable to available commercial rates and also by the accuracy of the time measurements of the operating hours which were made during the case study.

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