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Full Length Research Article

REPLACING CONVENTIONAL ENERGY SOURCES OF ELECTRICITY WITH SOLAR ENERGY IN THE UK AND IRAQ USING STATISTICAL INFERENCE WITH HYPOTHESIS TESTING

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ABSTRACT

Solar power represents a vast resource which could, in principle meet the world's needs for low-carbon power generation many times over. Recent growth in the use of photovoltaic (PV) technology (of around 40% per year) and rapid reduction in its cost (20% per doubling of capacity) has demonstrated the potential of solar power to deliver on a large scale. 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 and Iraq 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. Solar cells involve harnessing the energy from the sun to generate electricity and as such the amount of sunlight hours or solar insulation available in the country is of utmost importance. In this study a methodology has been developed to compare a model micro-business in the UK and Northern Iraq. The comparison shows that using statistically inference the different regions (latitudinally) in Northern Iraq have a reasonable constant supply of solar insulation compared with the U.K which shows that there is more variation and less solar insulation in the more northern regions of the country. Therefore, it is more feasible to replace the existing non-renewable fossil fuel sources with solar cells in all regions of Iraq than the U.K which requires further cost benefit considerations.

INTRODUCTION

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. The Sun's radiation provides on average 1.73 x 1017J of energy to the Earth every second.

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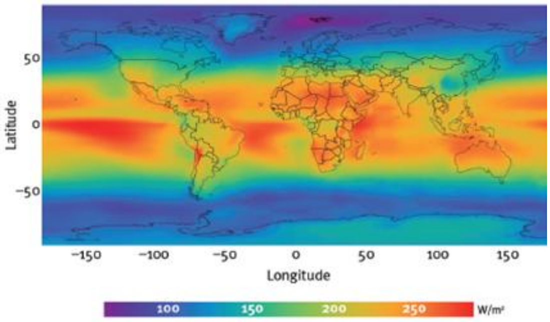
Figure 1 shows the annual average intensity of radiation over the Earth's surface, as can be seen there are variations due to the location of the region latitudinally. It is also known that the radiation varies between around 100 and 250 W/m^2 due to variations in latitude and climate (Nelson *et al*., 2014). 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 Northern Iraq. Analysis of the available solar energy for such a business in both the U.K and Northern Iraq has been carried. Statistical inference using hypothesis testing has been carried out to see if there is the same amount of solar insulation available in the different regions within each country or there are significant variations.

Background

The amount of electricity consumed from a non-renewable source was measured in a micro-business chosen as a business unit to test the system and develop protocols. These can be applied to other small business units. The energy consumed, the number of days the business was open and the number of customers served is shown in table 1 (Azabany *et al*., 2014).



Figur 1. Distribution of annual average solar irradiance over the Earth's surface

Table 1. 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

Also the relationship between the number of days open, units of electricity consumed and customers served can be seen in figure 2 as normalized data This paper considers a typical micro-business as above in both the U.K and in Iraq and considers the viability of such businesses using solar energy as an alternative to conventional fossil fuel sources which are limited in resource and damaging to the environment. The effective use of solar panels depends most crucially on the availability of the incoming solar insulation in the region and country of interest.

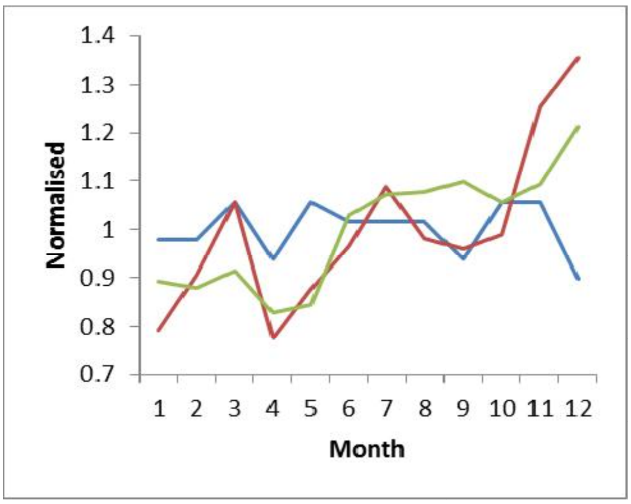


Figure 2. Normalized values of days salon is open (blue line), electricity used (red line) and customers (green)

Figure 3 shows a comparison between average daily sunshine in Iraq and the U.K for the year 2012 (Azabany *et al*., 2014). Previously, (Azabany *et al*., 2014) it was shown that using solar panel with efficiency of 20% can replace only 29% of the total electricity required to run this typical micro-business in the U.K. However, in Northern Iraq due to longer daily and annual daylight hours we can replace 88% of the energy needs with silicon solar cells. Our main consideration in this paper is to determine the feasibility of using solar energy in all the regions of the U.K and of Iraq. We employ the use of statistically inference methods using hypothesis testing to see if in the different regions of the countries we have a constant source of solar insulation or is there large fluctuations within regions to make solar panel implementation more difficult.

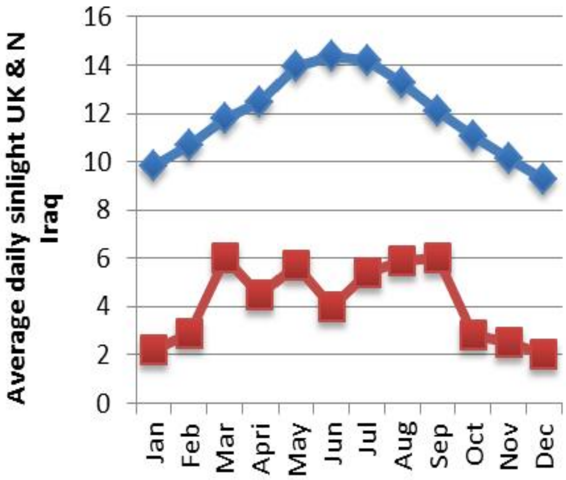


Figure 3. shows a comparison between average daily sunshine in Northern Iraq (blue) compared to UK (red) in 2012

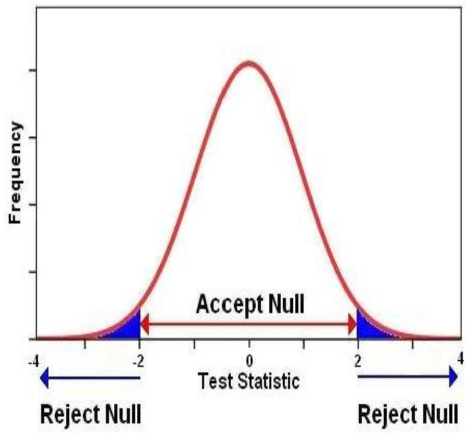


Figure 4. Choosing when to Accept and when to Reject the Null Hypothesis

MATERIAL AND METHODS

Statistical Background

We will be considering a two-tailed test see figure 4. A two-tailed test is one where H_1 involves testing for any (non-directional) change in the parameter (Albright, 2014). In our study we are interested in seeing if there is the same amount of solar insulation falling in all regions of the U.K and Iraq as we

IRAQ:

Table 2. Average daily solar insulation per month (kWh/m^2/day) in six cities of Iraq

Month	Arbil	Baqubah	Baghdad	Al Hillah	As Samawah	Al Basrah
Jan	3.69	4.36	4.33	4.2	4.24	4.34
Feb	4.16	5.33	5.42	5.11	5.01	5.25
Mar	5.12	5.74	5.71	5.5	5.47	5.39
Apr	5.46	5.35	5.33	5.68	5.67	5.42
May	6.06	5.93	5.92	6.18	6.17	5.95
Jun	6.62	6.58	6.56	6.88	6.79	6.6
July	6.52	6.24	6.22	6.54	6.6	6.39
Aug	6.51	6.49	6.47	6.67	6.58	6.32
Sep	6.32	6.07	6.05	6.34	6.36	6.06
Oct	5.12	4.98	4.96	4.91	5.03	4.92
Nov	4.11	4.14	4.11	3.95	3.39	3.9
Dec	3.74	3.99	3.96	3.87	3.85	3.78
	63.43	65.2	65.04	65.83	65.16	64.32
Average	5.29	5.43	5.42	5.49	5.43	5.36
SD	0.0692					

U.K:

Table 3. Average daily solar insulation per month (kWh/m^2/day) in six cities of U.K

Month	Aberdeen	Glasgow	Newcastle	York	Oxford	Southampton
Jan	1	1.13	1.21	1.16	1.29	1.51
Feb	1.88	2.1	2.23	2.06	2.05	2.45
Mar	2.6	2.89	3.17	2.85	2.77	3.28
Apr	3.44	3.87	4.14	3.64	3.68	4.42
May	4.08	4.57	4.9	4.24	4.18	4.95
Jun	3.93	4.39	4.65	4.09	4.21	4.89
July	3.75	4.16	4.49	4.07	4.26	4.95
Aug	3.5	3.97	4.32	3.83	4.17	4.79
Sep	2.96	3.31	3.56	3.16	3.27	3.85
Oct	2.01	2.22	2.56	2.28	2.42	2.74
Nov	1.16	1.36	1.44	1.32	1.54	1.77
Dec	0.75	1.13	0.95	0.94	1.06	1.19
	31.06	35.1	37.62	33.64	34.9	40.79
Average	2.59	2.93	3.14	2.80	2.91	3.40
SD	0.280					

move latitudinally, north and south in the region. Due the positions of both the U.K and Iraq with respect to the equator, we are expecting that the closer the region is to the equator the greater amounts of solar insulation is expected. Since, we are looking at the two countries separately, we are considering six cities from north to south in each country, (n) the number of data points is six and the standard deviation (σ) for the countries is unknown. With an unknown (σ) and a small sample size $n = 6$ which is much less than the required thirty data points, we must also use an estimate (s) for our (σ) given by:

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$$

Where $\bar{x}$ is the mean of our sample and n is the number of sample points.

There being some uncertainty in using (s) to estimate (σ) when a small sample size is involved, the t – distribution tables are used to find the critical values rather than the normal distribution tables.

The test-statistic is now:

$$\frac{\bar{x} - \mu}{s/\sqrt{n}}$$

Also, a sample size of n will have $n - 1$ degrees of freedom (df). The required significance level will be at 5% to determine the critical t – values. Due to the two type of errors Type I and Type II that can occur with hypothesis testing using a 5% significance levels gives a good balance between the risks of making Type I and Type II errors.

For our two countries U.K and Iraq, we are going to assume that our null hypothesis is that the mean amount of solar insulation is the same as the hottest region (i.e. the most southern region closest to the equator) in all parts of the country going further north. Therefore the alternative hypothesis will be that the mean is different from the hottest (southern) region.

$\mathbf{H_0}$: the amount of solar insulation is the same in all regions of the country (latitudinally) as the most southern region.

$\mathbf{H_1}$: the amount of solar insulation is different in the different regions of the country (latitudinally).

Solar Insulation Data for Six Cities in Iraq and U.K

Our data (Suri and Dunlop, 2005) for the daily average solar insulation in $kWh/m^2/day$ for both Iraq and the U.K for six different cities is shown in the tables 2 and 3 below.

CALCULATIONS AND RESULTS

For IRAQ:

$H_0 : \mu = 5.36$
$H_1 : \mu \neq 5.36$
Significance test at 5% gives a probability p = 0.975 and $\alpha = 0.05$ $n = 6$ number of data points and so degrees of freedom $df = 5$.

From the t – distribution tables (see appendix A) the critical values are found as t = $\pm$ 2.571

Using

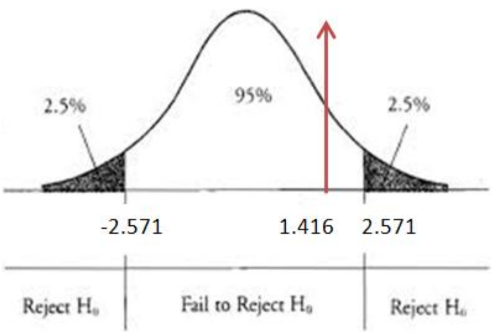
$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$$

and the test statistic as $\frac{\bar{x} - \mu}{s/\sqrt{n}}$

the data points for Iraq give $\bar{x} = 5.4$ and $s = 0.0692$ implies that the test statistic = 1.416.

$n = 6$ so $df = 5$ and $p = 0.975$

$t_{\frac{\alpha}{2}, n-1} = t_{0.025,5} = \pm 2.571$



So since $1.416 < 2.571$ H_0 is accepted and there is no significant evidence to suggest that there is any change average amount of insulation in the different regions of Iraq.

For U.K.

$H_0 : \mu = 3.40$
$H_1 : \mu \neq 3.40$

Significance test at 5% gives a probability p = 0.975 and $\alpha = 0.05$ $n = 6$ number of data points and so degrees of freedom $df = 5$.

Again from the t – distribution tables the critical values are found as t = $\pm$ 2.571

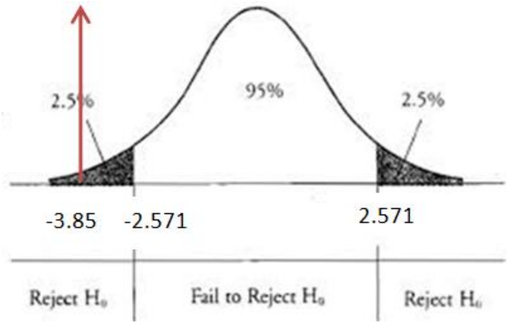
Using the data points for the U.K gives,

$\bar{x} = 2.96$ and $s = 0.280$

implies that the test statistic = - 3.85.

$n = 6$ so $df = 5$ and $p = 0.975$

$t_{\frac{\alpha}{2}, n-1} = t_{0.025,5} = \pm 2.571$



Since $-3.85 < -2.571$, hence H_0 is rejected, there is significant evidence to suggest that the average solar insulation is not the same as the most southern region. Looking at the data further suggests that as you go further north in the U.K then generally there is less solar insulation available.

Conclusions

A methodology to compare a micro-business in both the UK and Northern Iraq for energy utilization has been proposed. To show that solar energy is a viable alternative to conventional energy sources one of the most important parameter with the use of solar panels is the amount of solar insulation potential available in that region and country of interest. If there is a constant high amount of solar insulation available in the country then implementation and use of solar panels is a viable options and makes sense. If there are significant fluctuations in the amount of solar insulation within the different regions of a country then more serious considerations has to be given before implementation occurs.

What is seen from our data and statistical inference calculations is that in Iraq over the all the regions (latitudinally) on average the amount of solar insulation is close to the hottest region. There is a reasonably constant amount of solar insulation in the different regions of the country. However, the analysis for the U.K shows there is significant evidence to suggest that the amount of solar insulation is not the same as the hottest region and so further analysis is needed. When the data is examined further it indicates that the more northern regions of the U.K generally get less insulation than the southern regions. The implications for using solar energy as an alternative source of energy in both the U.K and Iraq is that countries like Iraq which have a good constant supply of solar insulation in all regions of the country throughout the whole year are very good places to use solar energy as an alternative source and typical micro-businesses as the one we considered in this study will benefit hugely by the utilization of solar energy. Countries like the U.K need to see more closely the data on solar insulation and look at the cost analysis to see if implementation of solar panels is appropriate in the different regions of that country.

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