ECONOMICAL ANALYSIS AND ENVIRONMENTAL IMPACT OF ENERGY USAGE IN MICROBUSINESSES IN UK AND KURDISTAN, IRAQ

by

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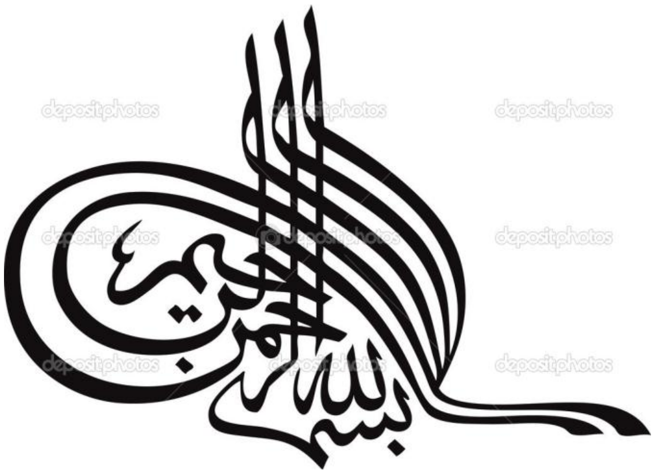

"In the name of ALLAH most Gracious and Most Merciful"

DECLARATION

I declare that while registered as a candidate for this research degree, I have not been registered candidate for any other award from an academic or professional institution. No portion of the work in this thesis has been used for another academic award. It is solely my own work.

Signature

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15 September 2014

ABSTRACT

Over reliance on fossil fuels, rising global population, industrialization, demands for a higher standard of living and transportation have caused alarming damage to the environment. If current trend continues then catastrophic damage to the earth and its environment may not be reversible. There is an urgent need to reduce the use of fossils fuels and substituting it with renewable energy sources such as wind, tidal and hydroelectric.

Solar source seems to be the most promising due to its environmental friendly nature, portability and reliability. This source was examined in terms of microbusinesses such as SMEs including hair dressing salon, education centre, fried chicken outlet and printing shop. Small businesses account for a large proportion of the economy. The analysis developed could be applied to small business to show their contribution to the carbon footprint and how this could be reduced using solar energy. The proportions of their current electricity usage that could be substituted with solar cells were calculated. Combined these have a significant impact. These businesses were considered for UK and Iraq with the former being more amenable to solar energy implementation.

Analysis of the four SMEs showed that the most energy intensive business was fried chicken take away using a large amount of electricity and the least energy intensive business was the education centre. In the latter in UK 57% of the electricity usage could be replaced by solar energy compared to Kurdistan, which generated a surplus energy that could be fed into the national grid. The gents groom hairdressing and blue apple businesses gave intermediate figures. Parallel conclusions were drawn regarding CO_2 emissions released into the atmosphere with education centre being the most environmentally friendly and the fried chicken the least.

In addition, a larger public space, an international airport data was analysed and the value of solar replacement demonstrated. The methodology and data analysis approach used may be implemented for other business units and larger public spaces such as hospitals, shopping complexes and football stadiums.

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DEDICATION

I dedicate this thesis to my

- Father - Saber
- Mother - Sabria
- Wife - Nashmeel
- Boys - Ayman, Shkar, Ahmad, and my little princess Sara
- Brothers – Zryan, Are and Ali
- Sisters – Akhter, Tavga, Naska, Ahang and Jeno.

Table of Contents

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1. Introduction

In this chapter, the background to energy sources currently used has been outlined to place the project into context. The aims and objectives are stated and the structure of the thesis is briefly outlined.

1.2. Background

1.2.1. Energy

Energy is an essential requirement globally transforming the way in which humans live, travel and work (Wang et al., 2014). All modern technology is reliant on a reliable supply of energy and therefore strongly affecting lifestyle. A strong connection exits between average life expectancy and the availability of energy (Hodgson, 2010). People in poorer countries, such as Asia and Africa have access to energy usage of between 0.01 and 0.1 tons coal per year and have a life expectancy between 35 to 45 years. People in Europe, Japan, and North America, use between 5 to 10 tons of coal per year and have an average life expectancy of between 70 to 75 years (Lee et al., 2012) Hence, there is a link between life expectancy and access to energy. There are 2 billion people without direct access to energy. Hence, improved wellbeing and better lifestyle massively impacted our growth in the total population. In 1900 there were 1.5 billion people on Earth and, a billion was added every 12 years (Jackson, 1978). A U.N report predicts that the global population will becomes 10 billion by end of this century (Mitigation, 2011). This will place further demand on the energy requirements.

1.2.2. Energy from fossil fuels

Approximately 86% of world's energy comes from fossil fuels such as oil, gas and coal produced from crude oil and residues from the ground. The technology for obtaining energy from fossil fuels is highly developed, reliable and with a good infrastructure for delivery in the developed countries (Phil 2010). The demand for energy is increasing rapidly due to the desire for modernization, better lifestyle and rising population (Bölük and Mert).

The increasing reliance on fossil fuels is causing major environmental, economic and political issues (Suranovic, 2013). This work will focus on environmental and economic impact. The political issues are outside the scope of this thesis.

i). Global warming

This has arisen due to rapid industrial developments, rising population and dependency on fossil fuels (Shahbaz et al., 2013). Burning fossil fuels in industrial plants, motor vehicles and machinery produces carbon dioxide (CO_2) above the earth's surface. This layer is getting thicker. The suns radiation strikes the surface of the earth and is reflected back into the atmosphere. As the CO_2 layer getting thicker a significant amount of radiation is unable to escape. Hence, the surface temperature has been increasing rapidly from the start of industrial revolution, from between 0.6-0.7 to 1.2^{o}C in the twentieth century. Most of this increase has happened in the last 30 years.

The consequence of global warming are frightening causing flooding due to ice caps melting, sea levels rising thus damaging our habitats with devastating economic impact (Sapci and Considine, 2014).

ii). Depletion of the ozone layer (O_3)

Burning of fossil fuels and use of CFC is causing the alarming depletion of the ozone layer above the earth's surface (Andersen and Lupinacci, 1988). The layer is becoming thinner and with holes in it. The ozone layer protects humans and other living species from harmful radiation from the sun. Further depletion of the ozone layer will increase risks of skin cancer and cause health issues (De Winter-Sorkina, 2001).

Therefore, after much debate and political action, technological and economic factors are seriously being considered. Far more needs to be done in order to reduce the environmental damage caused by humans. Urgent action should be on top of the political and scientific agenda.

iii). Energy crises

Fossil fuels originate from the ground, is finite and the increasing demand cannot be sustained. The consequences of energy running out will have a major detrimental global impact economically, on lifestyle and transportation (Griffin et al., 2012). It will set humanity back centuries in terms of development and lifestyle. The crisis needs to be overcome urgently and new sources of energy developed to replace existing sources.

Reliance on fossil fuels needs to be reduced. A reduction in the use of fossil fuels is essential and alternative and reliable renewable sources of energy are required to replace fossil fuel sources.

1.2.3. Renewable energy sources

A renewable energy originates from a source that will not run out even if it is used continuously (Herzog et al., 2001) (Cucchiella and D'Adamo, 2013). These include:

- i) Wind energy
- ii) Tidal
- iii) Biomass
- iv) Geothermal

v) Photovoltaics

vi) Solar thermal

vii) Energy from waste recovery

This project will focus on solar energy and discussion on other renewable sources will therefore be brief. Solar energy is an ideal replacement because it is renewable and harmless to the environment.

1.2.4. UK and Iraq context

In this study a comparison is carried out between UK and Iraq. The major differences between these countries within the context of fossil fuels sources and solar energy are as follows:

i) Iraq is abundant in oil and therefore is a cheap source of energy for its development and future whilst UK is reliant on fossil fuels from the Middle Eastern.

ii) The climate in Iraq with longer daylight and solar radiation intensity favours the implementation of solar technology as source of energy compared to the UK.

iii) The infrastructure for delivering energy from fossil fuels is much lass developed in Iraq compared to the UK.

1.2.5. Solar energy

The total solar energy absorbed by Earth's atmosphere, oceans and landmass is approximately 3,850,000 exajouls (EJ) per year (J.Chorley, 2010). In 2002, this was more energy in one hour than the world used in one year. Solar energy accounts for nearly one-sixth of the world's total low-temperature cooling and heating by 2050, according to the International Energy Agency (Canadell et al., 2007). This would reduce some 800 megatonnes of carbon dioxide (CO_2) emissions per year, or more than total German CO_2 emissions in 2009 (Riemer, 1996).

Research and development shows much promise in developing new generation of solar cells such as flexible organic solar cells (Hoppe and Sariciftci, 2004). Latest nanotechnologies will improve the efficiency and reliability of solar cells making it feasible to replace the existing fossil fuels energy sources with new generation of solar cells, which have a much higher efficiencies and reliability. Flexible solar cells wouild be less intrusive and cheaper than silicon solar cells and more efficient (Pagliaro et al., 2008). Silicon solar cells degrade over time and need to be replaced. The Earth receives 174 Petawatts (PW) of incoming solar radiation at the upper atmosphere (Vasiljev and Yurdanova, 2011). Approximately 30% of radiation is reflected back into space and rest of the radiation absorbed by clouds, oceans and land.

A great deal of work still needs to be done to make efficient, reliable and flexible thin solar cells that can be placed on roofs and windows without being visibly unattractive.

1.2.6. Small to medium sized enterprises

In 2011 there were about 4.5 million private businesses representing an increase of 94,000 since 2010, an increase of 2.1%. Their combined turnover was £3,100 billion employing 23.4 million people. SMEs of the represented 62.4% of the private sector were sole traders, 27.7% were companies and 9.8% were partnerships. SMEs accounted for 99.9% of all enterprises with 58.8% employment and 48.8% sector turnover. UK SMEs annual turnover is approximately £1 trillion (Antony et al., 2005). Clearly, SMEs are crucial in creating jobs and revitalising the economy. Thus, there is considerable potential to reduce energy consumption and replace a significant proportion of energy generation with solar energy. In SMEs the energy cost is given little priority due to lack of knowledge and expertise of entrepreneurs. Even though cost savings can be made in the long terms SMEs do not generally have the financial resources to appoint a dedicated energy manager to study energy utilisation and implement energy saving policies. Even though SMEs make little contribution to the energy agenda however when their combined contribution is considered the effect on energy efficiency and emissions is significant (Thollander and Dotzauer, 2010).

The focus of this project is towards SME type business for the following reasons:

- SMEs contribute to large percentage of overall employment.
- SMEs generated billions of pounds of turnover, representing a large of the overall UK revenue.
- SMEs energy requirements can be much more easily replaced with renewable compared to large companies.
- SMEs energy requirements and analysis is much simpler compared to large companies.
- Large companies tend to be multinationals and implementation of energy strategy towards renewable is far more complicated involving large number of stakeholders.

1.2.7 Microbusinesses or microenterprises

The majority of businesses operating in the UK and Kurdistan region of Iraq can be classified as microbusinesses or microenterprise (Hoffman et al., 1998). The terms are used interchangeable in the literature. These businesses are defined as having less than 10 employees and a turnover of less than £1.5. In the UK and Kurdistan most of these are family owned businesses with one or two people working in them. The major objective of owners of these businesses is to earn a living for their family (Matlay, 1999). Their growth occurs when there are changes in the family or when there is a need to generate larger income. In the USA 98% of the 28 million businesses are classified as microbusinesses or microenterprises. These types of businesses are very common worldwide including UK and in Northern Iraq microbusinesses account for 99.9% of all businesses (Hoffman et al., 1998).

Even though microbusinesses have been around since the beginning of the business trade the concept of microenterprise and microfinance was brought to worldwide attention in 1979 by Muhammed Yunis who founded the Grameen Bank (Bank of the Poor) in Bangladesh in 1976 by lending small amounts of money to the poor to help them start their own businesses and make them independent. The bank has grown from 15,000 borrowers in 1980 to almost 10,000,000 today with 97% of borrowers being women (Counts, 2008).

Microbusiness contribute enormously to the economy by creating jobs, providing income, strengthening power to purchase products, lowering costs and being located in convenient locations where they can serve their communities.

In this work the businesses that have been studied may be classified as microbusinesses and if these enterprises can to switch from fossil fuel sources of energy to solar source of energy then this would have a significant impact on the global warming, CO_2 reduction and sustainability.

1.2.8. Approach used this study

There are two major approaches to overcoming problems associated with fossil fuels. These include:

i) Energy management in order to reduce waste and improve efficiency.

ii) Replacement of fossil fuels with renewable energy. This was the focus of this study was on solar energy.

Energy management has expanded with agreements and partnerships between companies and energy providers to implement policies and systems to improve efficiency (Hitchens et al., 2003). For large companies energy is a significant component of the total costs and this approach is sensible. However, for SMEs the introduction of energy management is very limited for several reasons.

i) Energy costs is only a small proportion of the overall costs and therefore of limited interest.

ii) Expertise and experience regarding energy management and its implementation in SMEs is minimal.

The following energy management system has been proposed.

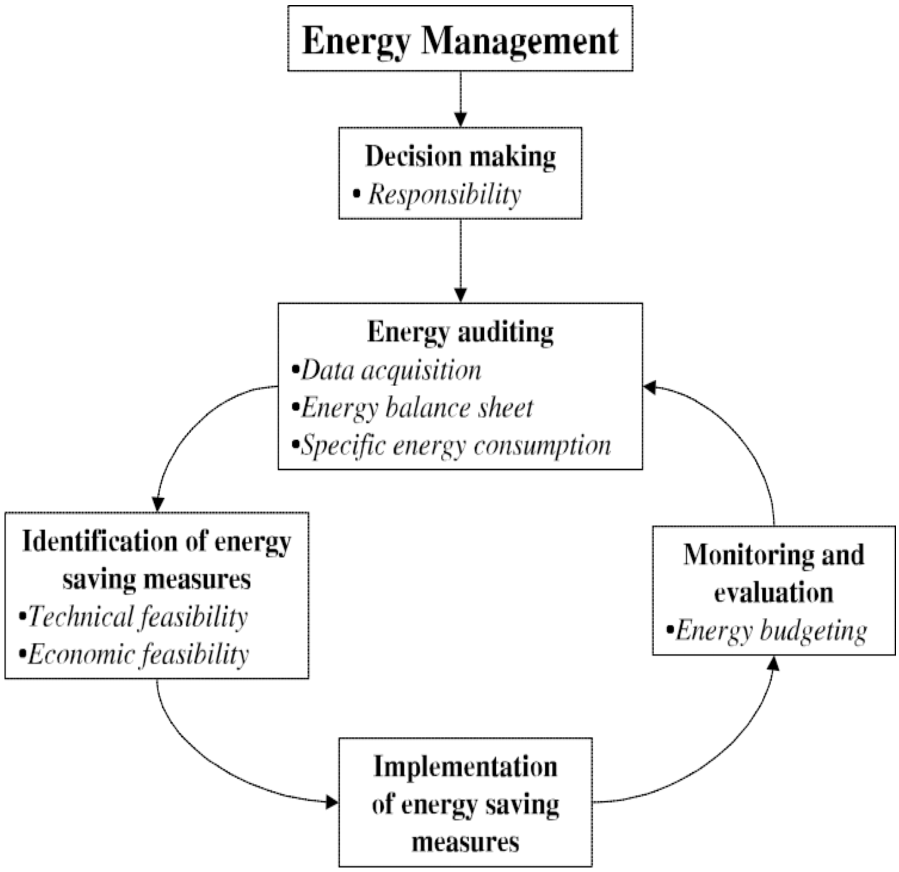


Figure 1.1. Structure of energy management programme in German SME, Adapted from: (Kannan and Boie, 2003)

The second approach is to replace existing fossil fuel sources with renewable energy (Lund, 2007). This study focuses replacing fossil fuel sources with solar energy. It compares its implementation in the UK and Iraq. This approach has been employed for the following reasons:

i) Knowledge of energy management concepts is very limited hence implementation on a large scale in SMEs would be very small with minimal impact.

ii) Replacing fossil fuels with solar energy is much simpler in SMEs

iii) The amount of energy used by SMEs is small and can be readily replaced with solar energy. Solar cell efficiencies are too small currently to replace the large energy demands of large companies.

iv) Electricity from solar cells is readily generated in Iraq due to favourable climate.

Data regarding energy utilization was collected from several SMEs in the UK and Iraq. Each component using electricity was considered for its power consumption and usage time. Components by component analysis was necessary since the electricity bill received from energy providers in the UK was accurate however the bill received in Iraq was heavily influenced by political connection of the business and did not accurately reflect electricity utilized. Obtaining access to information from SMEs was an arduous process and difficult to obtain appropriate approvals. Data from five businesses was collected.

i) Gents Groom Hairdressing Salon

ii) Blue Apple Printing

iii) Kansas Fried Chicken

iv) Kip McGrath Education

v) Sulaymanyah Airport

These represent small and large public places.

1.3. Aims and objectives

1.3.1. Aims

The aims of this project were:

- Analyse and assess the actual energy used in various components in several businesses.

- Assess the feasibility of replacing non-renewable energy resource with a sustainable energy source such as solar energy.

- Assess the potential of replacing solar energy with current supplier in one of the main International airport (Sulaimayah Airport), carry out a cost analysis and CO_2 reduction in Kurdistan, Iraq.

- Analyze actual solar radiation potential to generate electricity in the capital of the Kurdistan (Erbil City).

- Analyze solar potential between six cities in Iraq and UK examining the different levels of solar radiation power.

1.3.2. Objectives

The objectives of this study were as follows:

- To analyses a well-established business unit as a model system for other units. The unit chosen was the Gents Groom Hairdressing Salon. A detailed analysis of this unit will help to analyse and refine the methodology for further business units and larger complexes composed of multiple business units. Detailed level of each business unit is required at component level to elucidate the amount of energy used exactly since the electricity bill received by businesses vary depending on their political influence and other local factors.

- To carry out an evaluation and analysis of the current energy utilization in selected public places in the Manchester, UK and Kurdistan, Iraq. Individual business units were compared initially followed by a more complex scenario of a multiple units in public international airport.

- To compare the impact of non-renewable energy sources on the environment and the implications of the economic considerations for utilizing renewable energy source particularly solar instead of fossil fuel based resources. Solar energy is particularly attractive in the context of a Middle Eastern country such as Iraq and thus used for comparative purposes.

- To consider the economic impact of utilizing fossil fuels compared with replacing these with existing solar cells and to predict the impact of emerging solar cells such as flexible organic solar cells.

1.4. Structure of the thesis

Chapter 1 gives the aims and objectives of the project, background to energy needs and issues and the structure of the thesis.

Chapter 2 is a literature review of relevant work in the field considering the environmental impact, alternative sources of energy and the feasibility of replacing them with solar source of energy particularly in context of Iraq where solar radiation is abundant.

Chapter 3 describes the detailed methodology of the work carried out.

The following chapters are the results and discussion chapters.

Chapter 4 describes solar radiation, plant capacity of microbusinesses and reductions in the CO_2 emissions arising from implementing solar technologies.

Chapter 5 is based on a study and analysis of the Gents Groom Hairdressing salon.

Chapter 6 describes the results from the three SME case studies Blue Apple Print Ltd, Kansas Fried Chicken and Kip McGrath Education Centre. Current energy utilization is measured and the extent to which solar power has been used explored.

Chapter 7 describes the statistical techniques employed during the analysis of the businesses used in this study.

Chapter 8 gives the conclusions drawn from this study and suggested future work.

This chapter is followed by references and appendices including research papers published and accepted in peer reviewed journals.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

The global demand for energy is constantly increasing over the last century due to the growth in population, longer average life span, increased consumption and the increased industrialisation and development of emerging economies. These have serious consequences to the environment (Ocak et al., 2004). To prevent or reverse these trends several solutions have been proposed including:

- Using less energy by introducing energy saving measures
- Increasing energy efficiency
- Replacing energy generated from fossil fuels with renewable energy sources

To consider viable solutions a detailed understanding of how energy is currently being used is required. Methods of collecting energy utilisation data and their limitations need to be considered. Once reliable data has been collected it needs to be analysed and the various approaches to analytical processes considered.

Electricity is used for domestic, business and transportation purposes. Domestic energy and various energy saving measures have been examined extensively in the literature (Geppert and Stamminger, 2013).Transportation of goods and people also uses energy and is responsible for a significant amount of pollution of the atmosphere (Kiran et al.). These have also been considered in the literature and will not be included in the scope of this study. The third category to consider is energy utilised in businesses. There is some overlap between business category and transportation since many businesses need to transport their goods around the globe. Large businesses particularly in the manufacturing category are also highly energy intensive and these outside the scope of this study since it is difficult to obtain reliable data. Small businesses have the potential to utilise renewable energy sources and make a significant difference overall to the energy dilemma (Velik and Nicolay, 2014).

2.2. Industrial revolution and energy demand

Before the industrial revolution the worlds energy demand was relatively constant and sustainable. In the eighteenth century the industrial revolution started which created a massive demand for energy as production and consumption simultaneously increased (Sieferle, 2001). This demand has increased exponentially causing instability and depletion of ecological and environmental systems. The demand for energy from the developed world could no longer be supplied by steam and wood fuel (Ragauskas et al., 2006). The discovery of oil, gas and coal fuelled the age of airplanes, rockets, computers and automobiles. These continued to develop and aspirations for better lifestyle, travel and consumerism and the desire and emergence of developing countries further fuelled demand and rise in energy consumption (Lee, 2005). Hence, dependence on energy has become so critical and relies on a reliable and consistent supply of energy. The majority of fuel for energy generation comes from fossil fuels such as coal, oil and gas. An explosion in the human population from about two billion in 1930 to 8 billion caused the demand to increase even further. In 30 years since 1970 to the beginning of the twentieth century the energy demand has doubled (Krausmann et al., 2009).There are no signs of let up in energy demand globally with more nations emerging, such as, whose for improved standard of living with more automobiles, global travel and industrial development is still unquenched (Bhalla, 1992).

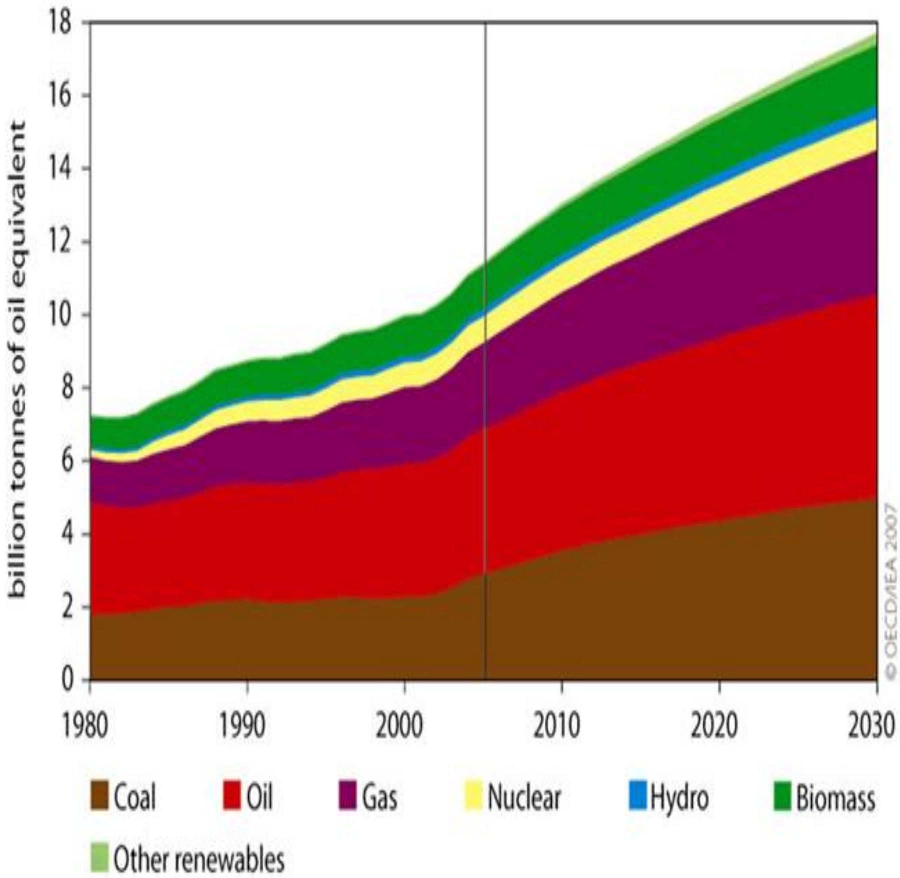


Figure.2.1.World Primary Energy Demand by Fuel.
Adapted from; www.co2captureproject.org/multimedia.

Figure 2.1 shows the various types of energy sources and their utilization from 1980 projected to 2030. It shows the usage of energy in terms billions of tonnes equivalent for coal, oil, gas, nuclear, hydro, biomass and other renewables. In all cases the utilisation has increases annually from 1980 to date and this trend is expected to continue into the future. However, encouraging there is an increased proportion of green energy usage as the years go by and awareness is raised globally of the imminent dangers of non-renewables for our planet (Koroneos et al., 2003).

Urgent action is therefore necessary to satisfy the energy demand in ways that will not threaten future generations and the welfare of the planet (Weyant et al., 1999). The Kyoto protocol requires collective international action globally to reduce carbon footprint with each country being responsible for reducing carbon emissions and switching to green sources (Lehmann, 2007).

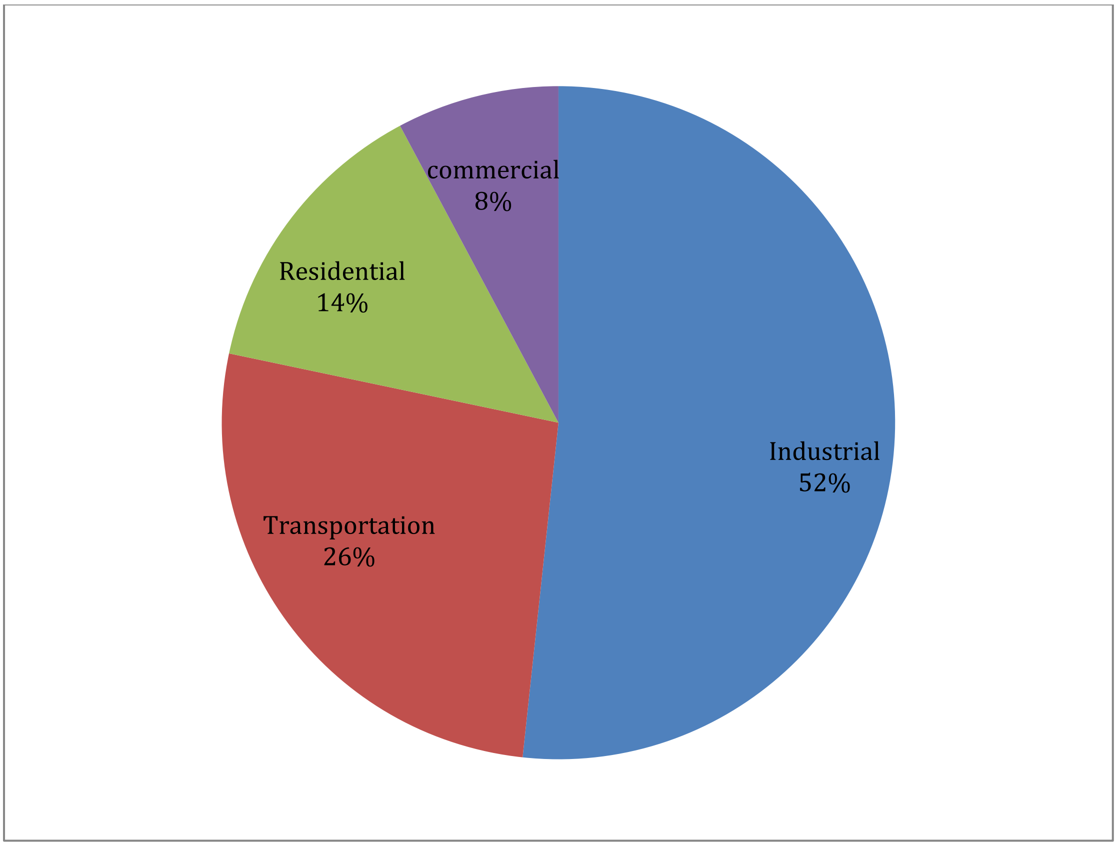


Figure 2.2. World energy consumption by the various sectors, Adapted from: www.news.thomasnet.com

2.3. Growth of the human population

About 80% from developing countries only consume 30% of global energy. The human population has risen due to advances in medicine, science, technology and transportation. Life expectancy has increased from 40 years of age to 80 years with 1.2

billion people added every 12 years (Hodgson, 2010). The global figure will increase to 10 billion by the end of the century The demand for energy will continue to increase and must be met by collectively (Cohen, 2003).

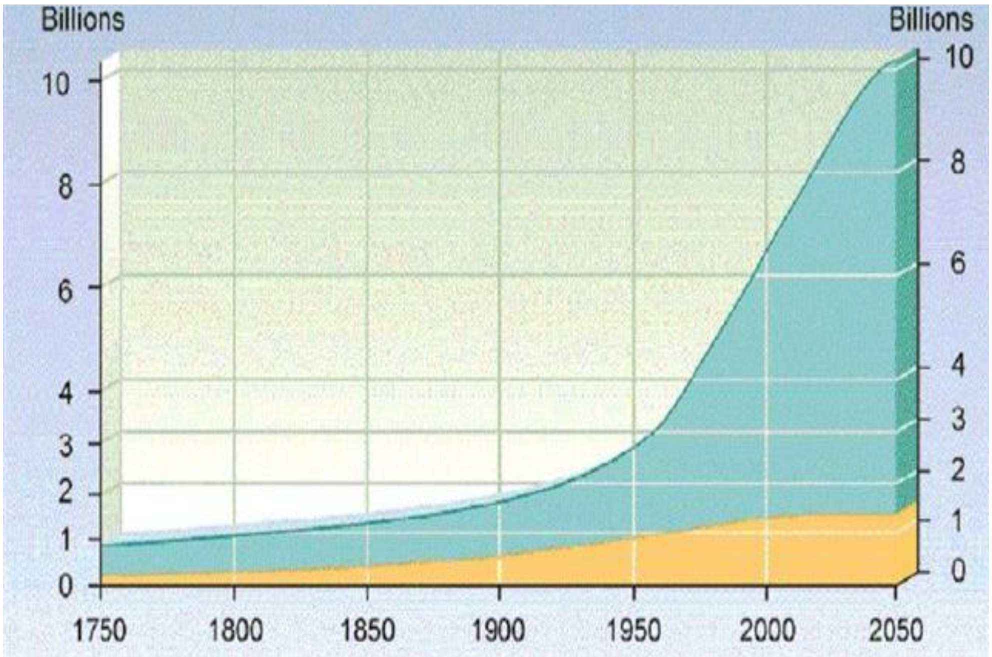


Figure 2.3. Population growth of the last 300 years (yellow – industrialised countries) and blue/green = represents developing countries). Adapted from: www.fewresources.org/ecological-footprints--human-impact-factors.html

The growth of population in 1800s was slow for thousands of years previously and reached one billion in 1820, then in the 1970s reached 3 billion and doubled in 30 years to 6 billion. Now the global population is doubling every 15 years and the figure above shows accelerating rate. This rate of increase is not sustainable with the energy resources currently available so alternatives are sorely needed (Holdren, 1991).

It is inevitable that as the population grows more energy will be required due to increase in housing, heating, cooling, lighting and transport. However, a robust energy efficiency education programme to teach people how to save and manage energy is essential (Levine et al., 1995). Government campaigns and advertisements on TV, radio and newspapers have been put in place in the UK to save energy. This type of programme to raise awareness of how to use and save energy is essential and urgently needed in Northern Iraq. Government subsidies mean that energy is cheap in Iraq and people leave appliances and lights switched on wasting energy and contributing to environmental problems. Hence, a cultural shift in attitude is required and this can only be done with an enticing campaign nationally (Zografakis et al., 2008).

In addition to changes in energy considerable benefits can be gained switching appliances to operate on renewable energy sources such as solar. Incentives to change for example to environmental friendly vehicles could also help to catalyse change from non-renewable to renewable sources as energy (Gillingham et al., 2006).

2.4. Energy from fossil fuels and non-renewable sources

Non-renewable energy sources cannot be created easily once they run out including coal, oil and gas, which have built over millions of years from decaying and fossilised materials from dead animals and plants under the ground with high temperatures and pressures (Hubbere, 1949). Nuclear energy comes from nuclear sources such as uranium which is a mineral existing under the earths crust and cannot be regenerated once used up (Macfarlane and Miller, 2007). Most of the homes, industrial plants and transport vehicles are powered non-renewable sources.

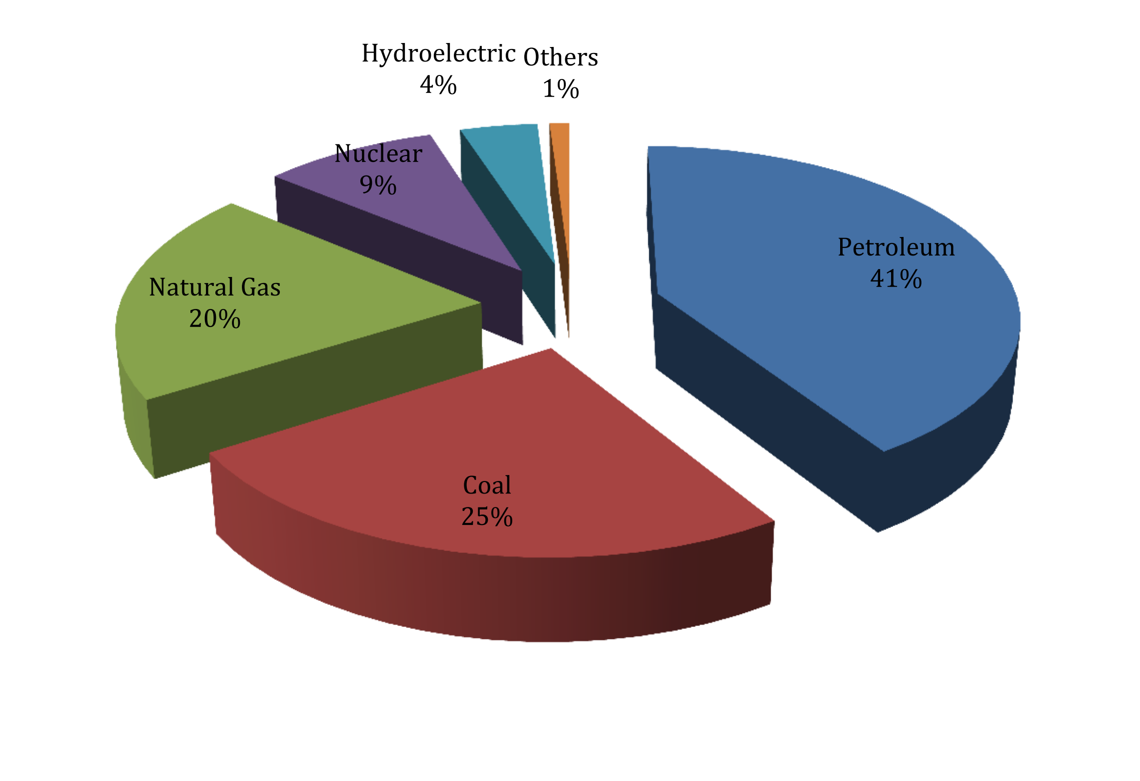


Figure 2.4. Sources of non-renewable energy, Adapted from:
www.altprofits.com/ref/se/nre/nre.html

2.4.1. Coal

Formed under high pressure and high temperature under the ground coal is a highly abundant source of energy. In USA about 50% of the electricity generated comes from burning coal. However, coal also produces greenhouse gases and is highly detrimental to the environment and its use needs to be decreased (Miller, 2004).

2.4.2. Petroleum or Oil

Oil is abundantly available in the Middle East and particularly in Iraq (Al-Ameri, 2011). It is a liquid containing numerous components, which are separated by fractional distillation into components use for fuel such as diesel, petrol, kerosene, gasoline, jet fuel, oil and waxes according to their boiling point. Oil is relative cheap fossil fuel but will also run out (Ibrahim and Hurst, 1990).

2.4.3. Natural gas

Natural gas arises from the decay of organic materials and can be extracted and used as fuel. Methane is the main component and is used for cooking in developed countries and piped into households (Paltsev et al., 2011). Other gases such as propane, ethane and butane are also used for business purposes and heating homes. This fuel burns cleanly but also generates CO_2 and is finite (Makogon and Cieslewicz, 1981).

2.4.4. Uranium

Uranium whose nucleus splits into more stable fragments generating very large amounts of heat that is used to generate electricity (Neff and Jacoby, 1980). The process for using this nuclear fuel for power generation is well developed and understood, however it has serious risks to health and it will also run out and cannot be regenerated (Hainfeld, 1992). The byproducts of uranium are hazardous and present disposal problems.

The main advantages of non-renewable energy sources are as follows:

- Currently they are readily available currently at low costs.
- They have been developed as good choices for powering vehicles from ground and air transportation.
- They are easy to produce and supply thus contributing to economic growth.
- It forms the basis of trade and business amongst countries that have non-renewable energy sources and those requiring it for their use.

The drawbacks of non-renewable sources of energy have been highlighted in later sections of this chapter.

2.5. Problems with energy from fossil fuels

2.5.1. Greenhouse effect and global warming

The global warming problems arise from using energy from fossil fuels from applications such as transportation (Schneider, 1989a), industrial processes and power stations (Figure 2.5). The greenhouse effect arises due to the build up of various gases in the atmosphere such as carbon dioxide, nitrous oxides and methane (Pearce, 1991). This layer lets solar radiation to cross through but does not large wavelength radiation pass causing a general warming of the earth biosphere and atmosphere. The effect is to keep the earth warm for life forms to thrive and prosper. Without this layer the earth would be about 30^{o}C cooler (Kasting and Ackerman, 1986). Despite its benefits there has been a substantial increase in the emission of greenhouse gases into the atmosphere due to the extensive use of fossil fuels which has made the greenhouse layer to be thicker causing less radiation to escape (Valley et al., 2002).

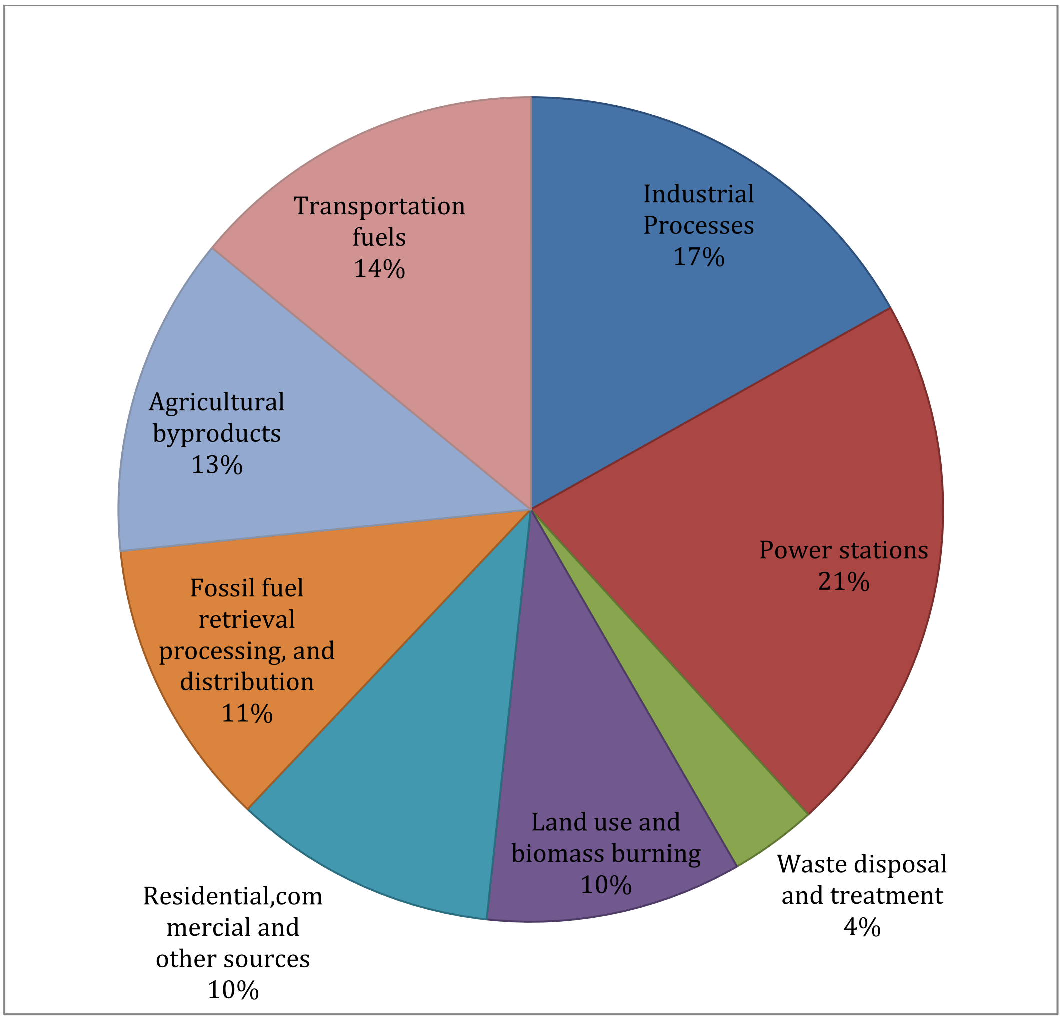


Figure 2.5. Proportion of energy from various sectors Adapted from: www.google.co.uk/search

CFC have a long life span and thus stay into the atmosphere (Shine, 1991). Hence, even if there was a complete stop to emission of greenhouse gases it would take over a decade to stop the earth's temperature from rising. Therefore, the temperature will continue to escalate. CO_2 contributes over 50% to the Greenhouse effect. Researchers estimate that over the last 100 years a temperature increase of 0.6^oC, which has caused sea levels to rise by 20 cm. Recent trends indicate that the temperature rise will be much more rapid in the future and the consequences very severe (Schneider, 1989b). Greenhouse emissions are stimulated by growth in population, transportation and economy and deforestation. Scientists are predicting that excessive global warming will cause changes to the climate causing ice caps to melt, rising sea levels and flooding (Mitchell, 1989).

2.5.2. Ozone depletion

Ozone (O_3) layer exists at altitudes between 12-25 km in the stratosphere (Solomon et al., 1986). It exists in natural equilibrium with oxygen and oxygen radicals.

$$O_3(g) \rightleftharpoons O_2(g) + O^*(g)$$

It absorbs UV (240-320 nm) and infrared radiation and protects inhabitant of the earth from harmful radiation that cause problems such as eye damage and skin cancer (Last, 1993). This layer has been getting thinner and scientists have notice holes in the ozone layer causing concern. The depletion of the ozone layer is caused by CFCs, halons (cholorinated and brominated compounds) and NO emissions (Ravishankara et al., 2009). CFCs are used as refrigerants in cooling and air conditioning systems and NO is released from biomass combustion, fertilizers, denitrification and burning of fossil fuels. These emissions attack O_3 converting it into O_2. In 1985 a hole was observed in the ozone layer above the Antarctica (Lorentzen, 1995).

Ozone layer depletion is a major crisis of our environment. Chlorofluorocarbons released disintegrate the ozone layer through attacking the O_3 molecule and converting it into oxygen (Karplus, 1992). The ozone layer’s hole in Antarctica in 1985 lead to anxiety throughout the world as it was clear that the natural system has been damaged by human activities. The probable effects of the ozone layer depletion on natural system and environment were not clear (Henriksen et al., 1990).

After global warming became apparent, CFCs were banned (Penner, 1999). The ozone present in the stratosphere at altitudes between 12 and 25 km making a natural equilibrium keeping responsibility for the earth throughout absorption of ultraviolet (UV) radiation (240-320 nm) and absorption of infrared radiation. The environment global problem is the stratospheric ozone's layer depletion, caused by the emissions of CFCs, halons (chlorinated and brominated organic compounds) and NO (Thouret et al., 1998).

Energy related actions are responsible only partially (directly or indirectly) for the emissions that creating the stratospheric ozone depletion. The main cause for ozone depletion has been CFCs, used in refrigerating equipment as refrigerants and air conditioning, and NO emissions produced by biomass combustion processes and fossil fuel, nitrogen fertilizers and natural denitrification.

2.5.3. Acid rain

Fossil fuels are burnt in vehicles, aeroplanes and industrial plants produce SO_2 and NO. These gases dissolve in water to produce acid rain.

$$SO_2\ (g) + H_2O\ (l) = H_2SO_3\ (l)$$

To reduce acid rain the amount of SO_2 and NO need to be reduced. Thus, the quantity of fossil fuels used for energy must be reduced. Catalytic convertors on vehicles are also a good way of changing harmful emissions into safe gases (Likens et al., 1996).

Volatile organic complex (VOCs), chlorides, trace metals and ozone also contribute to air pollution and acid precipitation. Evidences showing the acid precipitation's damages have been reported by Dincer and Rosen (Dincer, 2000).Other possible ways to reduce pollution involve using 3-way catalytic converters and cleaning coal before combustion.

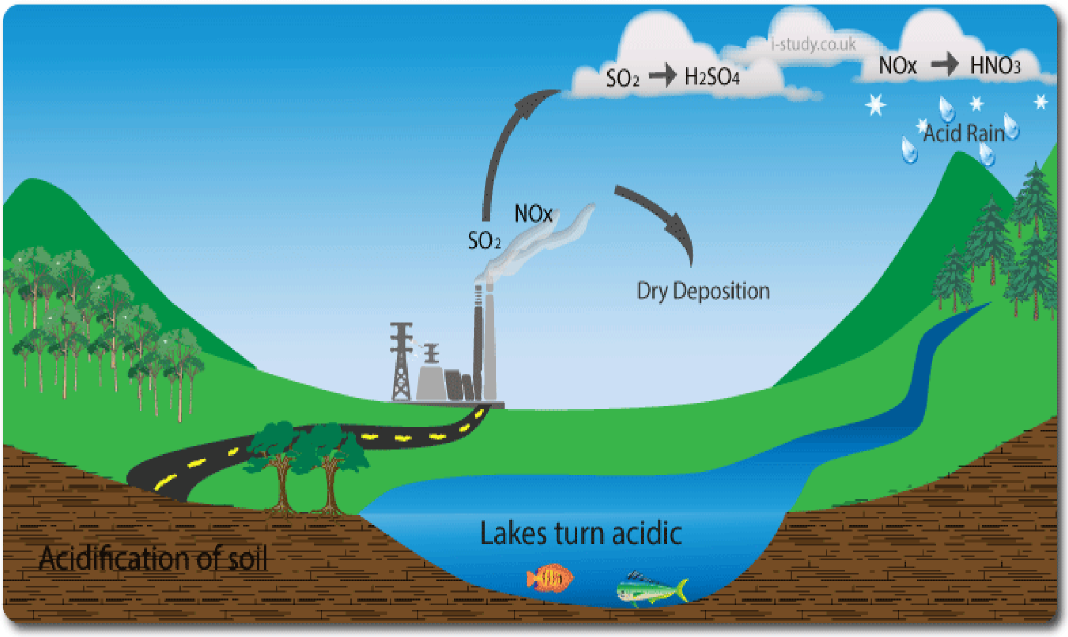


Figure 2.6. Emission of gases from burning fossil fuels causing acid rain. Adapted from: wwwnualgiponds.com/protect your ponds ph level from the effects of acid rain/

2.5.4. Rising CO_2 levels and global temperature rise

As result of increased population and industrialisation the CO_2 levels have risen drastically in recent years as shown in figure 2.7

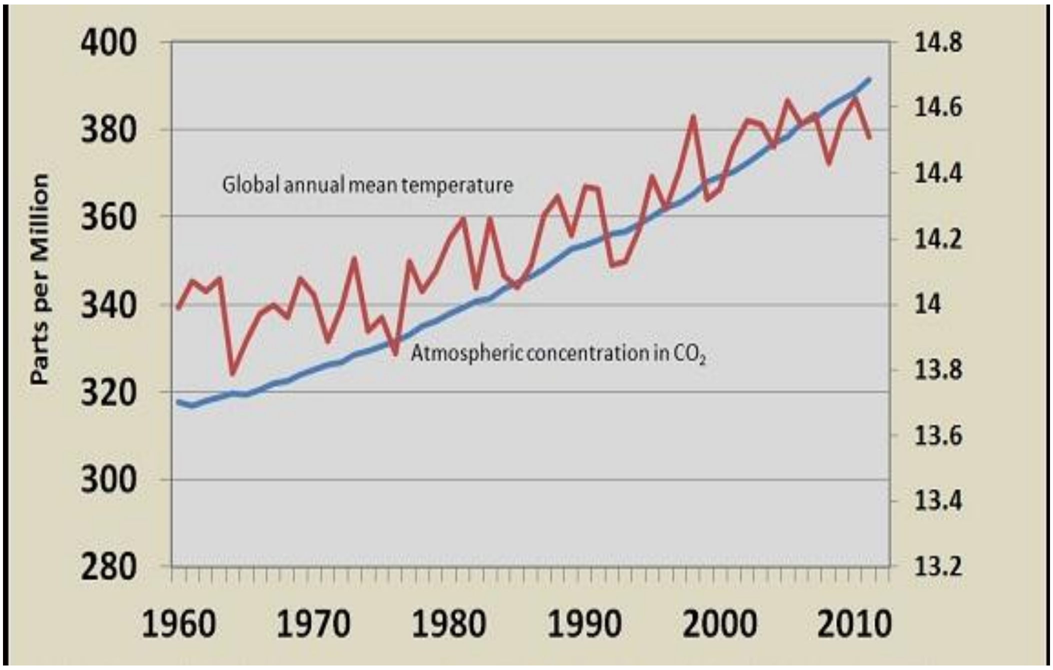


Figure 2.7. Rising CO_2 levels and earth's temperature for the past 50 years. Adapted from:www.principia-scientific.org/global-warming-from-co2-all-politics-no-science.html.

The rising global temperature problem needs to be fixed. It is causing natural disasters such as floods, forest fires and acid rain. For example, the temperatures have been rising from the start of the industrial revelation, which was 0.6 to 1.2^{o}C in twenty century with most of this increase occurring over the last 30 years. And 2^{o}C degree increase in temperature will cause biggest disasters to the earth (Hansen et al., 2006).

Government policies towards developing energy within the world energy markets will have an important role in energy consumption and its production (Kerr, 2001).

2.6. Carbon footprint

Carbon footprint of an individual is the direct effect from their action on the environment.

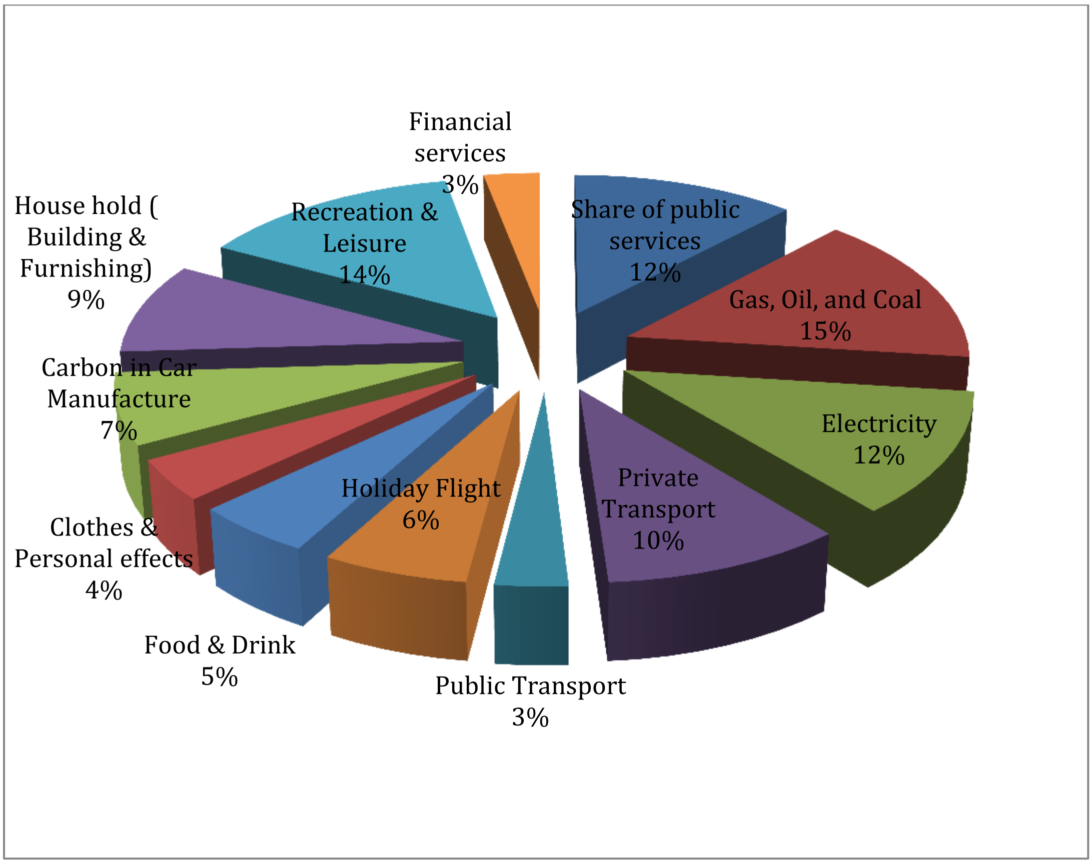


Figure 2.8. Carbon footprint from various sectors (Adapted from :www.eoearth.org/view/article/150926/

Large proportion of carbon footprint contribution comes from household electricity and transportation. The secondary carbon footprint is dominated by their personal products, diet, and clothes (Druckman and Jackson, 2009). The carbon footprint from various sectors is plotted in figure 2.8.

Fossil fuels used for transportation contribute to more than 13% of greenhouse gas emissions. Cars produce approximately 20 pounds of CO_2-eq per gallon. Air transportation has a much larger carbon footprint. In USA more than 20% of greenhouse gas emissions come from heating and cooling of homes (Dietz et al., 2009). Agriculture accounts for about 14% of overall greenhouse gas emissions worldwide. In the USA eating food is account for 17% of total consumption of fossil fuel, and an average carbon footprint for American individuals diet is 0.75 tons CO_2-eq, this figure is without adding food transportations. On average to transport food is 1,500 million between the production point and market. The average carbon footprint for meat is 1.5 tons CO_2-eq, which is much larger than vegetables, fruits, and green.

Dependency on fossil fuels over the next 30-40 years by getting policies and political action to move forward (Hertwich and Peters, 2009).

2.7. Solutions to energy and environmental problems

Several solutions to energy savings and environmental problems exist (Pohekar and Ramachandran, 2004). These include reducing the use of energy from fossil fuels, improve energy efficiencies of equipment and buildings and replace fossil fuel sources with renewable energy sources. This study focuses on the latter solution of replacing fossil fuels with renewable energy resources. Solar energy is attractive and forms a major part of the solution investigated in this work (Panwar et al., 2011).

2.7.1 Replace fossil fuels with renewable sources

Renewable energy sources will never run and the energy can be generated at the same rate as it is used. Renewable sources only provide less than 20% of the total energy requirements globally however, there has been an exponential growth recently in the availability of renewable energy from various sources with huge investments being made in developing the technology for energy generation (Gross et al., 2003).

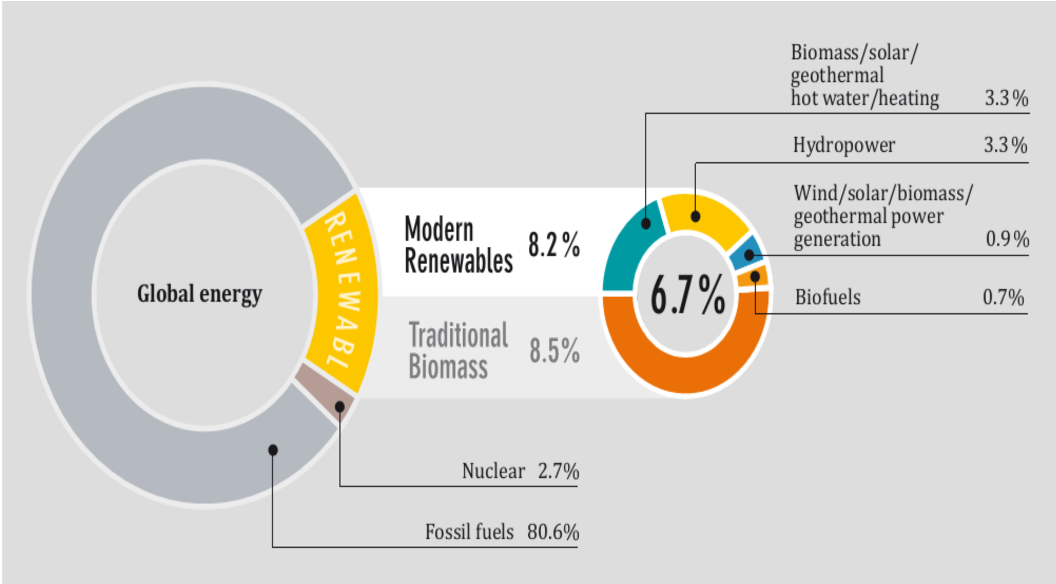


Figure 2.9. Renewable Energy Share of Global Final Energy Consumption in 2010. Adapted from: www.democraticunderground.com

The contribution of renewable energy sources is expected to increase and offer a viable solution as alternatives to fossil fuels. Switching to renewable sources offers substantial contribution towards global warming, climate change and environmental sustainability as well as growth in the economy and job creation worldwide (Twidell and Weir, 2006).

2.7.2. Wind energy

Wind energy comes from the uneven heating of the atmosphere, irregularity of the earth and the rotation. The flow of wind can be used to generate electricity with windmills, turbines and generators to create electricity (Burton et al., 2011). The kinetic energy of the rotating blades is converted into electrical power, which can be used in homes, school and businesses. Wind turbines are normally installed in open locations offshore to take advantage of power of wind. The increase in wind power has been the greatest amongst all renewable energy sources with over 80 countries employing wind turbines for electricity generation with large increases in capacity. Five nations contribute 66% of the global wind energy, in US (2.5 GW), Germany (1.8 GW), India (1,8 GW), Spain (1.6 GW) and China (1.4 GW). In the UK the number of wind farms have increased from the first wind farm in 1991 to over 200 producing in excess of 2.5 GW and could provide about 2% of the UK energy requirement. USA and China have driven up the wind capacity from 238 GW to 282 (Klaassen et al., 2005) GW showing a 20% increase. This increasing trend in wind capacity is expected to continue in the near future (Saidur et al., 2010).

2.7.3. Tidal waves

Tidal waves are one of the most reliable and predictable sources of energy available. Billions of gallons of water stays above their usual level and under gravity generate tidal waves. These generate electricity at lower tide naturally by constructing tidal barrages through estuaries (Lindzen, 1981).

A recent study has shown that over the last 20 years 565 GWh has been generated from tidal waves (Roussak and Gesser, 2013). In the UK there is a proposal to extend the 8.6 GW Seven Barrage by 16kn across the estuary, which is expected to generate 17 TWh of electricity each year equivalent to 4% of all the electricity generated (Blunden and Bahaj, 2006).

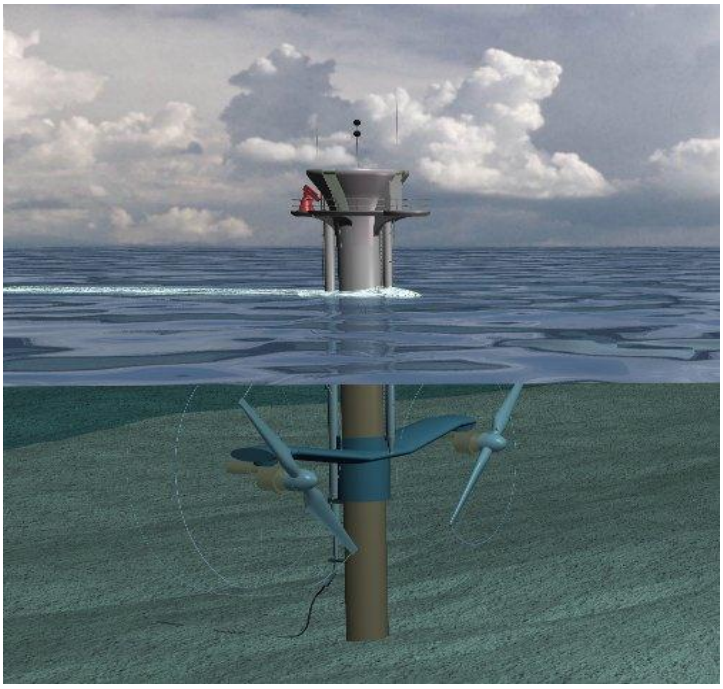


Figure 2.10. Picture of use of tidal waves .Adapted from:
www.homefootprint.info/OceanEnergy.aspx

Tides connected to existing turbines at the bottom of the sea in places with a high tidal velocity or places with fast ocean currents generating electricity from water flow.

2.7.4. Hydroelectric power

This is one of the oldest forms of electricity generation contributing about 15% of the global electricity and growing 35 annually (Arvanitidits and Rosing, 1970). Three main forms of hydroelectric power exist.

- **Run of the river** is suitable in situations will little variations in flow rate throughout the year. Generators and turbines are installed either in the dam or located alongside it. Dams use river flow to make a hydrostatic head. The technique may be applied to tidal barrage. In many cases additional flow passages to avoid upstream flooding along the river (Paish, 2002).

- **Diversion** from the water supply is taken from the dammed lake or river into a remote power-house containing the turbine and generator. Low-pressure tunnel or canal lakes take water into end point take back to river to carry on route.
- **Catchment schemes:** man made or natural reservoir is used to collect rainfall and water, and making a hydrostatic head and turbines installed in lower level are also fed by pipes or tunnels. A pumped storage system use hydropower to make electricity in a double reservoir system. At time of low demand electricity is used to pump water to higher basin and extra power is release when demand is high matching demand and supply (Poff et al., 1997).

Figure 2.11. Hydroelectric power generation plant. Adapted from: www.justvj.com/Hydro.aspx

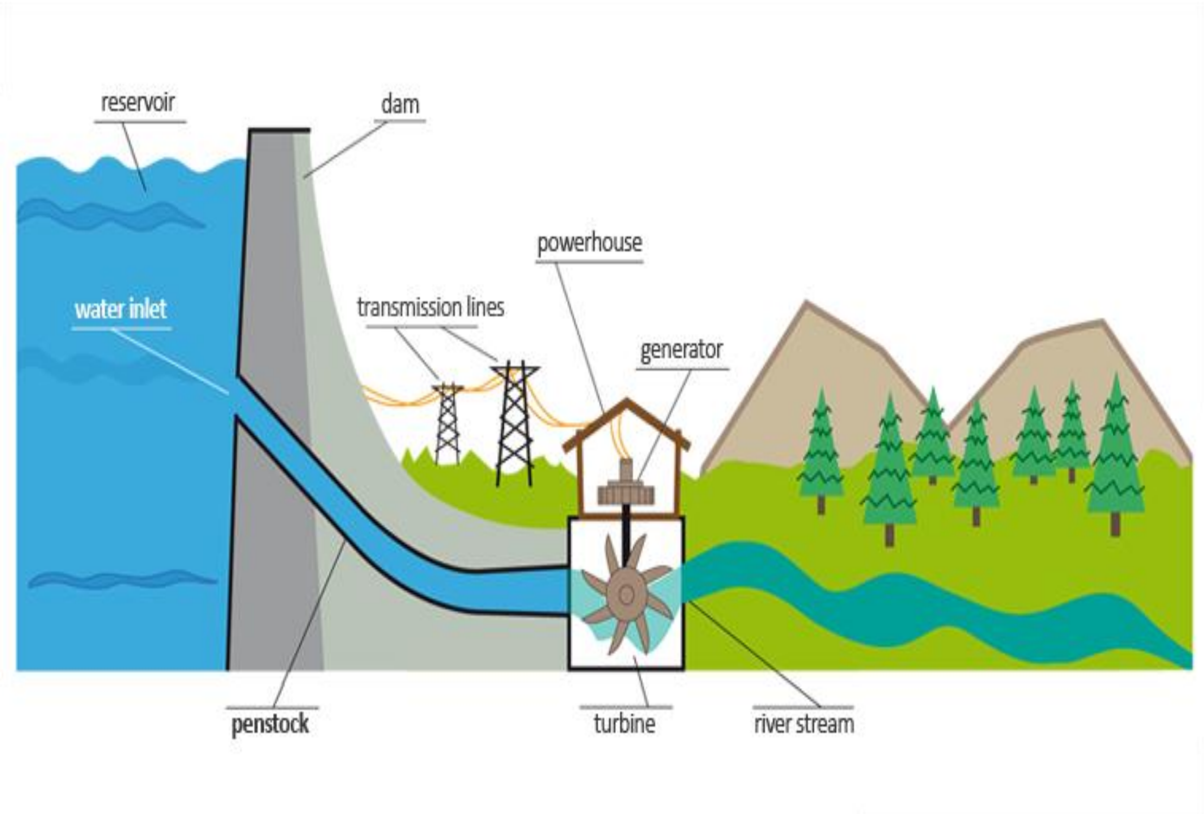


Figure 2.12 Hydroelectric power generation .Adapted from :
www.goodenergy.cl/eng_hydropower.

2.7.5. Biomass Energy

This energy is derived from biological materials obtained from living plants and animals or organic matter and is used directly for electricity, heat or fuel in households and transportation (Ravindranath and Hall, 1995). It can be easily stored and converted to heat, electricity or chemical energy. Globally it is estimated to generate 53EJ and about 86% used for heating and cooking and the remaining use to make electricity and as a biofuel for transportation, which has recently increased at a rate of 27% for biodiesel and 17% for ethanol (Ravindranath and Hall, 1995).

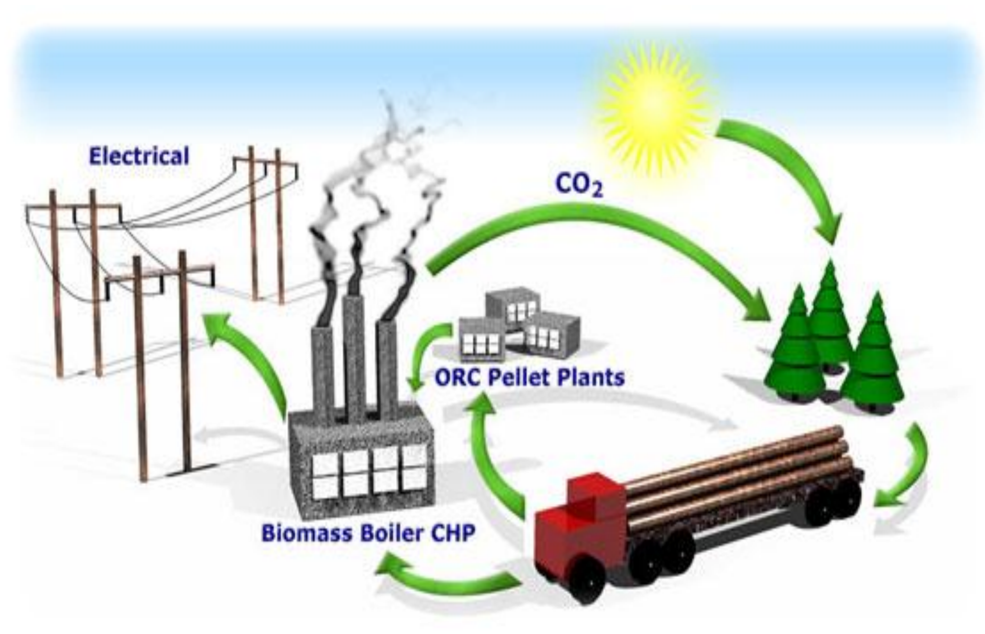


Figure 2.13 Biomass source of electricity .Adapted from:
www.cleangreenenergyzone.com/biomass

2.7.6. Geothermal energy

Geothermal energy comes from high temperature water and steam from the earth. It is a sustainable source of energy. It can be harnessed from large power stations to simple pumping systems. Geothermal sources produce energy at a competitive rate. Heat and electricity are more valuable than hot water hence has been the main focus of resources for power generation (Barbier, 2002). In 1913 the first power geothermal power station produced 250 kW and currently the Larderello produces 5TWh per year providing over 1M households in Italy. More than 24 countries use geothermal power stations (Fridleifsson, 2001) for electricity and 70 countries for heating. The potential for these station ranges from 35 to 2000GW with a installed global capacity of 10,715 MW. Three main types plants are common which are; dry steam, flash and binary cycle power plants.

Geothermal power plants require lengthy development times, high cost and risk of exploratory drilling.

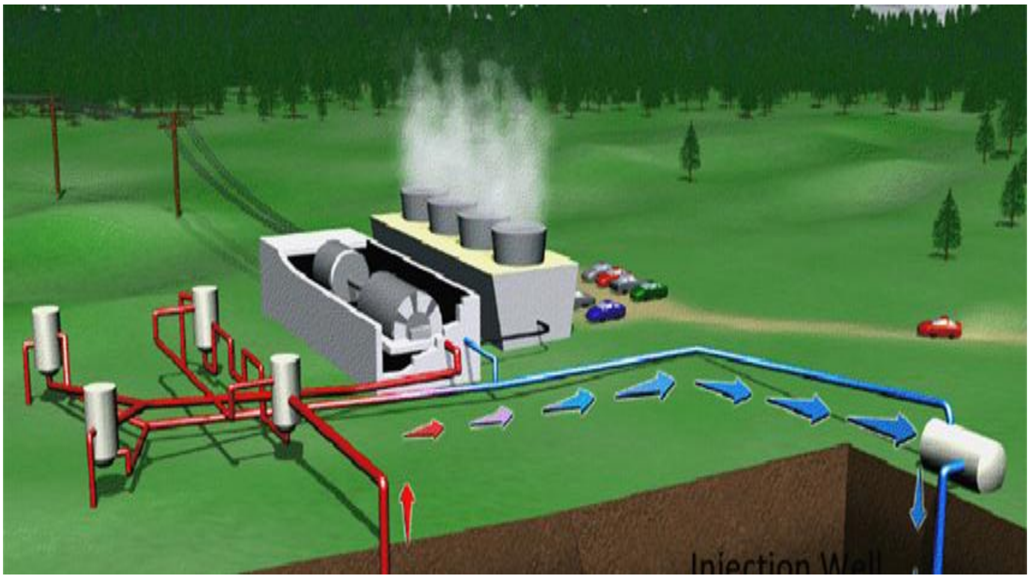


Figure 2.14 Geothermal energy generation .Adapted from: www.top-alternative-energy-sources.com

2.7.7. Organic Rankine Cycle

Low-grade heat sources with temperatures between 60-200^{o}C use waste heat, solar heat and geothermal heat can be used to an alternative source to produce electricity (Yamamoto et al., 2001). Organic Rankine Cycle (ORC) generation has a simple structure at low cost, and existing technologies can be used. Organic substances are used as working fluids to use low grade heat source which consists of an evaporator, turbine and a condenser. ORC consists of four processes (Wei et al., 2007).

i) The working fluid is pumped from a low pressure to high pressure with the pump requiring energy.

ii) The liquid at high pressure is heated after it enters the boiler at constant pressure using an external source with a dry saturated vapour.

iii) The dry saturated vapour expands through a turbine, which generates power whilst decreasing the temperature and pressure and some of the vapour condenses.

iv) The wet vapour enters a condenser and at constant pressure becomes a saturated liquid.

This system does not generate any exhaust gases such as CO_2, CO, NO_x and other pollutants. The thermal energy is converted to mechanical energy in the generator and then to electricity. The thermal efficiency of Rankine cycles is low and operating at low temperature and therefore the organic materials used must have low latent heat and high density. These increase the turbine inlet mass flow rate. ORC (Quoilin and Lemort, 2009)

2.8. Solar energy

This harnesses the energy directly from the sun to produce electricity. Approximately 5.4 million EJ per year solar radiation reaches the earth with 30% being reflected back (Liou, 2002). Solar energy can be transformed into electricity using solar panels. Solar collectors can supply almost 50 million households with hot water and more heating to homes. At Kramer Junction, California the largest solar plants can produce 354 MW of electricity to supply most of Southern California. Organic photovoltaic is promising, cheap and produces electricity (Bube, 1983).

Figure 2.15 Solar panels .Adapted from: www.org/post/solar-energy-rainy-day

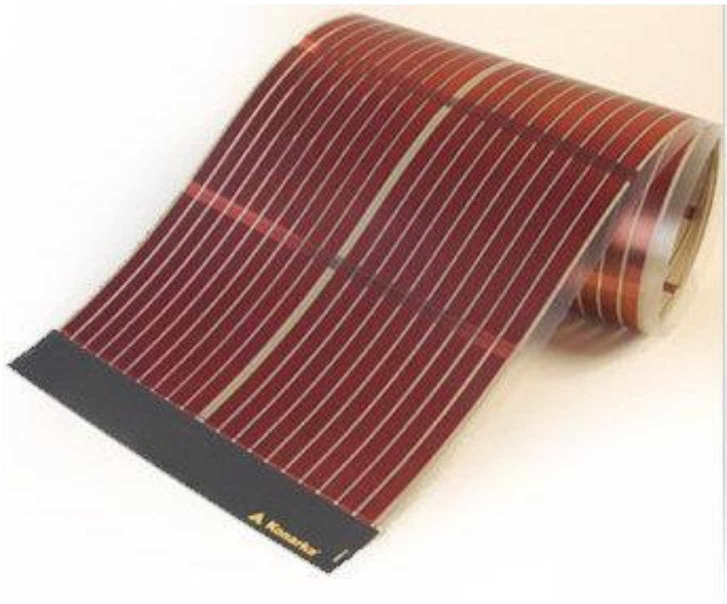


Figure 2.16 Flexible organic solar cell .Adapted from: www.gizmag.com/world-record-efficiency

Figure 2.17, Flexible organic solar cells on windows .Adapted from: www.dailyfusion.net/2013/11/swisstech-convention-center-features-multicolored-solar-panel.

Powering of electric devices mostly use the grid and bulky energy solutions such as batteries. Thin, flexible, lightweight energy sources will contribute applications such as autonomous, wireless, and flexible systems. Soft polymer batteries in the market with a low capacity (Krebs et al., 2010). Lightweight, miniaturized energy-harvesting solutions have been shown such as microvibration energy harvesting, but many of them extremely application specific, expensive, complex to manufacture, and inflexible. Solar cells with silicon-based can achieve 20% in power conversion efficiency (PCE), but have high manufacturing costs. Organic solar cells (OSCs) is far cheaper due to the solution of polymer ingredients (Kalowekamo and Baker, 2009) being used. The polymer can be printed in thin, flexible substrates using roll-to-roll, ink-jet, or different print-based fabrication, avoiding costly equipment. Latest technological development in OSCs supported their power conversion efficiency (PCE) to over than 8% with much lower cost of manufacturing equipment also increasing PCE, OSCs now can provides more attractive offer and expected to significantly enter silicon-based solar cells in cost competitiveness (Zweibel, 1999).

The first generation of solar cells used silicon, which is one of the most abundant elements on earth. This material was the basis of microelectronics devices with the advent of the silicon chip and the technology for making solar cells employed the knowledge and experienced gained in the semiconductor industry. This enabled solar cells to be produced on a mass scale allowing large GW of electricity to be produced (Braga et al., 2008). The manufacturing of solar cells involved production of silicon, cell fabrication and module assembly. Different types of solar cells can be manufactured including single crystal, polycrystalline, amorphous and ribbon silicon (Markvart and Castaner, 2004). Crystalline silicon modules started in 1963 when Sharp Corporation made commercial 242W PV modules on a lighthouse. This technology accounted for 87% of global PV sales in 2010 with efficiencies ranging from 14-19% even though higher efficiencies have been quoted in research and development studies. Improvements in the technology, materials and manufacturing enabled the costs to be kept down and would enhance efficiency (Shah et al., 1999).

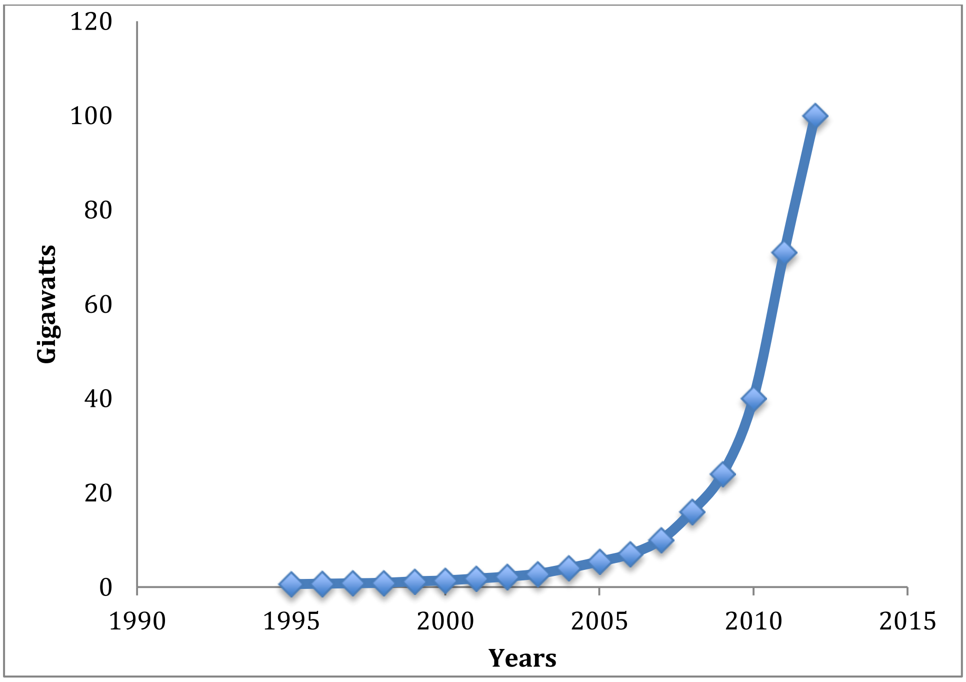


Figure 2.18. Global solar capacity over a couple of decades .Adapted from: www.abb-conversations.com/2013/12/7-impressive-solar-energy-facts-charts/

Over the last 20 years thin film solar cells offered lower cost than crystalline solar cells and production on a large scale hence increasing solar panels have been installed all over the world offering the potential to replace fossil fuel sources if electricity (Chopra et al., 2004). Thin films offer the possibilities of flexible and lightweight structures that could be installed on building components. These have included amorphous silicon, cadmium telluride and copper indium diselenide solar cells.

CdTe solar cells are well known and developed and offer higher efficiencies they may be of limited large scale use due to Cd being toxic and Te is not as abundant as Cd thus raising questions about sustainability. $CuInSe_2$ solar cells offer highest efficiencies and commercial cells are available from various companies. However, issues of toxicity and relative abundance prevent their widespread long-term use (Wu, 2004).

Amorphous silicon solar cells offer greater potential for cheaper and larger scale substrates. Large flexible modules suitable for curved surfaces on roof and side of building have also been developed. Presently their efficiencies are low (10-15%) and much reduced power output over time (15-35%) with irradiation and dust degrading their performance. Deposition techniques allow production of large areas up to about $2m^2$ (Green et al., 2012).

The next generations of solar cells are being developed and there are some commercial offerings. They include the following:

- Concentrating Photovoltaics
- Dye-sensitized solar cells
- Organic solar cells
- Novel and emerging solar cell concepts.

Organic materials based PVs could be fabricated as thin, flexible sheets using conventional printing techniques has the potential of controlling and saving significant costs and materials whilst reducing the impact on the environment (Brabec et al., 2014). Organic photovoltaics can potentially replace Si-PVs however, they need to be able to convert 17% of solar radiation into electricity, be fabricated at low cost using roll-roll manufacturing, reducing amounts of raw materials used and be environmentally friendly (Spanggaard and Krebs, 2004).

The disadvantages of emerging organic photovoltaic technology are:

- They have a shorter lifetime.

- They get damaged by UV radiation, oxygen and moisture in the atmosphere

The electrical energy generated must be stored. This can be achieved using polymers printed on thin, flexible and lightweight substrates using roll-to-roll, inkjet or other print based fabrication methods thus reducing capital manufacturing costs compared to silicon. Recently, their efficiency improved to about 8%.

Integrating energy system joins polymer energy storage films with organic solar cells in a thin, compact configuration can be considered as a flexible energy stack. These energy stacks can be printed on a roll as flexible film. The stack can be protected from both sides from UV radiation with a plastic film. The amount of light transmitted depends on the composition and thickness of the protecting film. When 100-200 mm thick then 70-90% of light can be transmitted. The flexible energy stack combination of OSC-OES is a platform technology that can deliver an integrated solution of energy. The flexible energy stack design requires a consideration of manufacturing cost as a critical factor (Jensen et al., 2012).

The third-generation novel solar cells under developments rely on using quantum dots/wires, quantum wells, or the technology of super. They can concentrate the solar radiation to achieve high efficiencies by overcoming the conventional (crystalline) cell thermodynamic limitations (Musa et al., 1998). These are still in the research phase and far from the market. Nanotechnology can adapt the active layer to obtain a better match to the solar spectrum (Soga, 2006).

Solar thermal technology utilizes sun's energy to generate heat. It is low cost, environmentally friendly and used to heat water or other fluids and in hot counrties in the summer power cooling systems (Mills, 2004).

In microbusinesses such as those studied in this work solar thermal systems have the following advantages:

i) They reduce electricity bills because hot water is required and a saving of up to 70% is feasible.
ii) They are sustainable and provide a good return in investment.
iii) They reduce the carbon footprint by using solar sources rather than fossil fuels, which release harmful carbon emissions.

Solar heating systems are simple and work in the following way.

i) Solar thermal collectors installed on the roof and absorb solar energy from the sun.
ii) Solar fluid circulates through collectors by a low-energy pump heat the water in a storage tank.
iii) The solar heated water is fed into the primary water heating system.
iv) The water is hot and does not require further heating before use or less time and energy is needed to heat the water to the desired temperature.
v) Therefore the utility bills will be much lower for heating water.

2.8.1 Advantages and disadvantages of renewable sources

The advantages of renewable energy (Zahnd and Kimber, 2009) are as follows:

- They are renewable and can be sustained and will never run out.

- The facilities general require very little or no maintenance.
- Fuel come from natural resources thus have lower operational costs.
- There are no emissions or wastes generated.
- Provide jobs and economic growth in many areas due to increased services.

The disadvantages of renewable are as follows:

- It is difficult to generate large concentrated amount of energy as traditional fossil fuel sources.
- Reliability is also an issue since natural sources are dependent on weather conditions, which are unpredictable in certain areas. For example wind power requires strong winds and solar power needs clear skies and sustained sunshine.
- When natural sources are not available then the capacity to generate energy is much lower producing uncertainty and poor reliability.
- Existing cost of energy from these sources are greater than traditional fossil fuels due to new technology having very high capital costs.

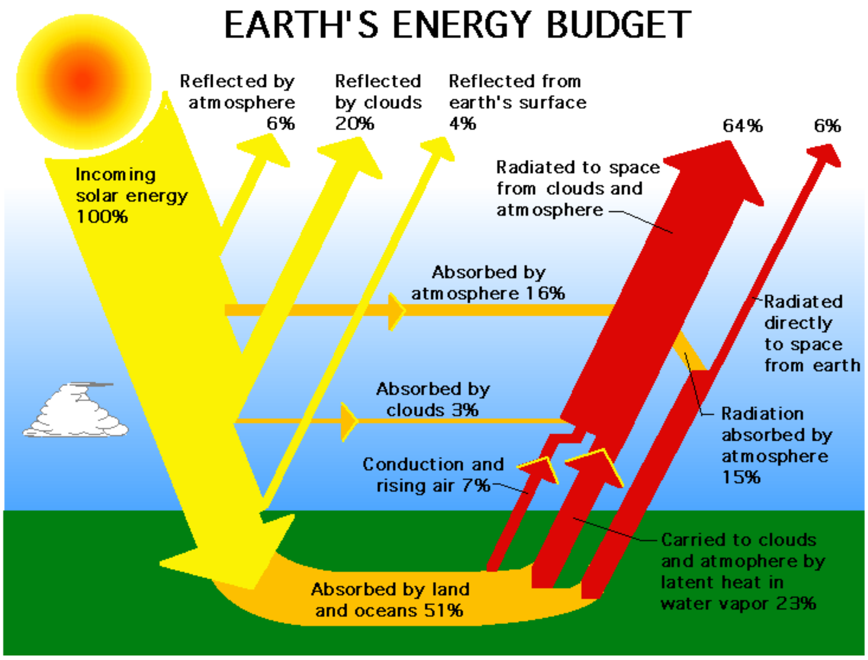


Figure 2.19. Earths energy budget. Adapted from:
www.edro.wordpress.com/energy/earths-energy-budget/

Solar energy is an abundant energy resource. Indeed, in just one hour, the solar energy intercepted by the Earth exceeds the world's energy consumption for the entire year.

2.8.2. Measurement of solar radiation

The amount sunlight at particular location at a given time is an important consideration (Bahm, 1977). There are two common methods to characterise the radiation of solar and they are solar radiance (radiation) and solar insolation. The solar radiance is a direct power density within kW/m^2. It varies during the day from 0 kW/m^2 at night to highest which rich 1kW/m^2 indicating that solar radiance is depends on local temperature of weather and the location. Furthermore, to take the measurement of solar radiance a pyranometer (measuring global radiation) or pyrheliometer (measuring direct radiation) can be used (Iqbal, 1983).

The potential of solar energy available on daily and monthly bases at the site for solar energy application, not only in amount but in quality, particularly its spectral composition is important. Solar radiation energy and its spectral distribution under all atmospheric conditions is undertaken also at many radiation networks around the world (Brock, 1981).

2.9. Solar energy potential in Iraq

Iraq has its unique set of characteristics. The Gulf wars destroyed the infrastructure and skills. These need to be rebuilt with its new energy requirements using renewable energies such as solar. Iraq has a good electrical network before the war with 32 power stations with a capacity of 10,200 MW (Keegan, 2010). The country has favourable conditions for implementing solar solutions to its energy requirements compared to UK. Kurdistan is located in a sunny belt between 34^0 42" N and 37^0 22" N latitudes and is ideally located geographically with respect to solar energy potential. Kurdistan- Iraq's solar energy potential is considerable. It has total annual average of sunshine of about 2979.5 hours (8.16hours/day) with a total annual average solar radiation is 1803 $kWh/m^2/year$ ($4.94 kWh/m^2/day$). It has extreme climatic conditions between summer and winter reaching higher than 45^oC with long daylight hours and intense solar irradiation and cylcones in the winter with average temperature -15^oC to 15^oC. Therefore, it is sensible to consider replacing fossil fuels with solar irradiation for source of energy thus reducing environmental problems. This important source of energy has been largely ignored due to lack of understanding and experience at government level hence national support for renewable energy programmes has been minimal (Paasche and Mansurbeg, 2014).

In this project a study of the current energy sources, utilisation, management and economic aspects in public places, such as SMEs and the much larger airport in Kurdistan, Iraq, will be undertaken.

Energy supply in Kurdistan is unreliable and in short supply. Another problem effecting energy supply is economic and political instability in Iraq. Solar can offer a partial solution and solve the energy crises in the Kurdish region. Iraq needs to urgently address its rapidly growing of electricity requirements for its economic development (Foote et al., 2004).

2.10. Types of SMEs and their energy needs

Companies can be defined as either large corporations or small to medium enterprises (SMEs). The government defines SMEs as companies in different categories, a small business with 1-49 employees , medium-size business with 50 – 249 employees, and a large business size is the one with 250 employees or over. Latest figures from government suggesting that estimated UK annual turnover is over £3 billion a year (Blackburn et al., 2006).

This study focuses on the SME sector even though contribution to energy utilised and CO_2 emitted is very small, however, their combined effects is a major contribution. Implementing solar solutions in SMEs is much easier than in large corporations and thus the beneficial effect on the environment substantial.

There are two types of SMEs classified as

- Manufacturing companies
- Service companies

Many companies have combined elements of service and manufacturing. For the purposes of replacing fossil fuel based energy supply with solar based systems it is easier to implement solar solutions in service companies which use computers and telephones because energy demands are less intense than manufacturing companies relying on heavy equipment. Service companies include transport companies and much work has been done on using renewable sources such as biodiesel (Lukács, 2005).

2.11. Energy studies in SMEs

Energy management and analysis have been carried out in large companies since they have the resources and commitment to assign such tasks to employees. However, energy is only a very small proportion of the overall business costs and therefore SMEs pay little attention to energy analysis and management. The literature available on energy studies in large companies is more prolific than in SMEs (Ali et al., 2010).

Kannan and Boie investigated the role of energy management practices in a German bakery and found that its role is increasing due to major industrial companies collaborating with energy service providers to improve energy efficiency (Kannan and Boie, 2003). They concluded that SMEs do not focus on energy management due to limited resources, expertise and energy is only a small proportion of total manufacturing costs. Guidelines were developed for entrepreneurs to implement energy management and found that a 6.5% reduction could be made on the total energy bill and reduce CO_2 emissions.

Onut and Soner analysed the energy use and efficiency of SMEs in the Turkish manufacturing sector (Önüt and Soner, 2007). In turkey SMEs constitute 98.8% of all corporations and the industrial sector energy costs are 35% of the total energy costs. Hence, a reduction in energy costs is highly desirable and improvements in efficiency will impact on profitability and market share. They used data from 20 SMEs for envelopment analysis (DEA), a linear programming model for deriving the comparative efficiency of multiple-input multiple-output decision making units (DMUs). Each DMU was evaluated in terms of a set of outputs that represent its successes and a set of inputs representing resources. Energy management program is important for effective use of energy for maximum production. This study showed that there is significant potential to save energy in manufacturing companies.

Subrahamanya investigated the relationship between productivity, energy intensity and economic performance in SMEs using a case study of brick manufacturers in India (Bala Subrahmanya, 2006). Labour efficiency is essential in promoting energy efficiency and economic performance in small-scale brick manufacturers using similar technology. Companies with higher labour efficiencies had lower energy intensities and were more profitable and competitive. Often technological up-grading is suggested as a way of improving energy efficiency and economic improvements. However, high capital investment prevents such measures being implemented. Brick manufacturing is a labour intensive business and predominantly based in rural areas in India. A negative relationship with energy intensity and a positive relationship with the ratio of value added to value of output was found using regression analysis. An increase in labour productivity resulted in bringing down energy costs. Regression analysis showed that

SMEs where productivity was higher the energy intensity was lower with higher returns compared to those where labour productivity was lower the energy intensity was higher which were confirmed with the Chow test (Bala Subrahmanya, 2006). The Chow test is used to test whether two different sets of data are equal. It is a statistical and econometric test, which uses linear regression on two different data sets. Its use is common for time series analysis to test for evidence of structural breaks (Toyoda, 1974). It is used to determine whether independent variables have different impacts on different subgroups of a population or country (Schmidt and Sickles, 1977). Hence, when technology is similar in SMEs then improving labour skills and efficiency is an important strategy for improving returns and improving competitiveness.

Kostka et al analysed at the financial, informational and organisation barriers to improving energy efficiency in SMEs in China using information based on a survey with semi-structured interviews of 480 SMEs (Kostka et al., 2011). Results suggest that the largest barrier to energy efficiency improvements was found to be informational. Financial and organizational constraints were also found to be significant. In addition, three further barriers were indicated these are role of family ownership, lax enforcement of government regulations, lack of government support and lack of skilled labour. Lack of awareness or knowledge of energy saving equipment or best practice in their business was evident in 40% of companies surveyed. Chinese government could play a active role in disseminating information about energy efficiency related information in the SME sector, which contribute to more than 50% to emissions. Of the companies surveyed 21% installed energy efficient equipment, 4% took loans to invest in energy saving measures and less 3% appointed an energy manager. About 54% planned to purchase additional or replacement equipment for energy saving measures. SME managers feel that they are poorly informed about energy saving measures and investment opportunities. Growing SMEs are more likely to implement energy efficiencies measures. Financing, information dissemination and training could improve energy efficiency in SMEs.

2.12. Application to public spaces in UK and Iraq

In this research applications to small and large public spaces will be studied. Specifically the following:

- Public places in UK and Iraq containing individual units and larger airport.
- The feasibility of replacing existing situations with solar energy and models depicted to give greater insights into whether commercially viable solutions can be implemented.
- Since, Iraq is being reconstructed on a large scale with development taking place rapidly it is envisaged that if public places can be designed at the onset then large energy gains and economic advantages can be realised. The concept of designing solar sources into the system at the outset is attractive.
- In addition, considerable research is being carried out using nanotechnologies to develop highly efficient large-scale solar cells. These have the advantages of higher efficiencies than conventional silicon solar cells due to the large surface area and better materials.

2.13 Microbusinesses and solar sources of energy

As mentioned in the previous chapter, almost 99.9% of the businesses in Iraq are microbusinesses and in the USA 98% of businesses are microbusinesses (Way, 2002).

Similarly microbusinesses constitute a very large percentage of the overall businesses worldwide. It is highly promising that the advantages of solar power lend it to be highly suitable for implementation in these type of businesses(Brett et al., 1996). This applies equally to using solar for both generation of electricity and heat. If these businesses can be persuaded to switch from using solar power instead of fossil fuels then the global impact on the environment and sustainability would be enormous. This study focused on the impact of switching from fossil fuel sources to solar on microbusinesses in the UK and Northern Iraq. The findings are readily adaptable to other countries in the Middle East and Europe and indeed globally.

2.14. Conclusions

This literature review has shown that SMEs contribute a significantly energy utilisation in the UK and Iraq. Fossil fuels can viably be replaced with renewable energy sources such as solar energy and trends in solar cell development are likely to yield a potential solution to problems generated by an over reliance on fossil fuels. The implementation of solar energy solutions in Iraq in microbusinesses is important due to favourable daylight hours and solar irradiation. Solar solutions are much easier to implement in SMEs than in large corporation and the combined impact is likely to be much greater.

CHAPTER THREE

METHODS AND ANALYSIS

3.1. Introduction

In this chapter the approach and methodology used for data collection from various businesses is described. The tools used during the operation of several businesses are described. The analysis methods used are described.

3.2. Methodology

3.2.1. Business selection and agreement

Selection, agreements and the study of several small businesses are described. Several dozen businesses were contacted and invited to participate in the study. Majority of the businesses invited declined due to sensitivities having their business under scrutiny. Four businesses agreed to participate, which included Groom Gents Hair salon, Blue Apple Printing, Kansas Fried Chicken, Kip McGrath Education Centre and Sulaymanyah Airport. The methodology and the details of the study were agreed and a contract agreement signed regarding free choice, confidentiality and operating principles.

The project has gone through the standard University of Central Lancashire approval processes though appropriate committees. The committees suggested actions and changes, which were completed to their satisfaction prior to formal approval being granted. A transfer report and viva has also been passed to progress to the PhD phase of this project.

3.2.2. Staff meetings

The manager/owner of the business met with staff and briefed them about the study and the types of data being collected and introduced the researcher and his background and purpose of the study.

3.2.3. Data collection

i). Groom Gents Hairdressing

The tools used for styling and cutting hair were identified and their selection and use explained to the researcher. These included scissors, large clippers, small clippers, hair dryer and shower. The other appliances, which used electrical energy, were also identified. The opening and closing time were determined and the days when the data would be recorded agreed with management and staff. The beginning and end of the tool cycle were agreed in order to minimise variance between tools and stylist using the tools.

The hair salon offered several styles of haircut and these were explained to the research along with the appropriate tools employed for the operation. Since each customer is an individual with particular taste and requirement their satisfaction was of primary important and therefore there some variance in time and tools used.

The electrical ratings of each tool and appliance were noted and later used to calculate the number of units of electricity used during various haircuts and customers.

The start of each tool use cycle began the moment the stylist picked up the tool from the tool rack and the end defined as the moment the tool was placed back in its original place. The stylist agreed that the tools would be placed in their exact positions when not in use and not left on the bench introducing a degree of discipline for accurate measurement of usage time. A stopwatch was used for timing the cycle from beginning to end. The timer was started as soon as the stylist picked up the tool and stopped as soon as the tool was placed back on the rack and the time was recorded. This was done for each tool and customer.

The measurements were carried out as discreetly as non-obtrusively as possible so that the stylist and customers were not disturbed and operated normally.

In order to assess the feasibility of replacing the electrical energy from fossil fuel sources various solar options were explored. The efficiency and active area were determined. The possibilities of installing solar cells on the roof were investigated and future projections regarding flexible organic solar cells explored. The window area was measured to determine active installation area and efficiencies project obtained from the literature. One of the objectives of this project was to reduce the amount of CO_2 the selected businesses emitted into the atmosphere from their use of non-renewable fossil fuels. This objective could be achieved easily by replacing all or a proportion of the electricity usage with silicon solar cells currently or in future with flexible organic solar cells.

The annual electricity usage was obtained from the electricity bill from the energy supplier, which included the units used, unit cost and overall total amount on a monthly basis. This enable a comparison between the total cost and electricity usage with electricity used by the tools and appliance.

ii). Blue Apple Printing

The appliances using electrical energy were identified and their power ratings were noted. The on times were noted over a period of time. The opening and closing times of the business were noted.

The equipment used for printing include the following:

- Large format printer
- Copier 1
- Copier 2
- Document Centre
- Guillotine
- Heat Press
- Laminator

The annual electricity usage was obtained from the energy supplier including units of electricity used, the unit cost and total cost. This was itemised on a monthly basis.

The feasibility of using solar cells was investigated by measuring the roof and window areas for potential installation and obtaining efficiency and active solar cell areas from the established literature.

iii). Kansas Fried Chicken

Kansas is a take away franchise based which uses considerable amount of energy in preparing cooked goods. It employs the following equipment from which electricity consumption data was taken:

- Pressure Fryer
- Open Fryer
- Heated Display
- Breading Table Marinator
- Wet Heat Bain Marie
- Heated Chip Scuttle
- Cooler

iv). Kip McGrath Education Centre

Kip McGrath Educations Centres is an international franchise teaching Maths and English to children from the age of 5 to 16 years old. They have hundreds of centres in the UK, New Zealand, Australia and Europe with a proven system.

The system uses very small group teaching up to five per professional teacher with each child having their own computer. Most centre open after school hours between 4pm to 9.00pm and Saturday from 9.00 am to 12.30 pm. The energy utilisation involves electricity for use of computers, printers and heating and lighting.

A typical centre will have 3 groups running simultaneously with 15 computers in total and an administration computer and general heating and lighting. This study utilised the Bradford North Kip McGrath Education Centre as its focal point for analysis.

The electricity data was collected and data for each component used.

- Computer 1
- Computer 2
- Computer 3
- Computer 4
- Computer 5
- Computer 6
- Computer 7
- Computer 8
- Computer 9
- Computer 10

- Printer 1
- Printer 2

- Kettle
- Microwave
- Lighting and heating

3.3. Data analysis

The data analysis involved correlating various variables with one another and obtaining statistical information the data. This was achieved using two main packages, EXCEL and MATLAB. These packages enabled trends to be identified and correlations to be explored. Curve fitting was used extensively to identify positive or negative relationships between variables.

Since the data analysis were routine and simple nature EXCEL was used due to its availability, ease of use and the competence of the candidate. MATLAB was used because it has extra features that could have been useful for this study such as curve fitting and to establish detailed mathematical relationship.

3.3.1. Regression analysis

The correlations between various variables were identified using simple regression analysis using the following methodology (S.Hadi, 2012) . An example is illustrated below, however this analysis was carried out using software packages EXCEL and MATLAB.

For the purposes of illustration consider the relationship between the number of customers served and the units of electricity consumed. Intuitively, it is expected that there will be a strong positive correlation between the number of units consumed and the number of customers served. When more customers are served then more electricity will be use.

Customers served (x)	**Units consumed (kWh) (y)**	**xy**	**x^2**	**y^2**
630	331	208530	396900	109561
620	379	234980	384400	143641
645	442	285090	416025	195364
585	325	190125	342225	105625
595	367	218365	354025	134689
725	404	292900	525625	163216
755	455	343525	570025	207025
760	410	311600	577600	168100
775	402	311550	600625	161604
745	414	308430	555025	171396
770	525	404250	592900	275625
855	568	485640	731025	322624
8460	**5022**	**3594985**	**6046400**	**2158470**

Table 3.1. Calculations for regression analysis

The mean values of x and y are calculated as follows:

$$\sum x/n = \frac{8460}{12} = 705 \qquad \text{Eq. 3.1}$$

$$\sum y/n = \frac{5022}{12} = 418.5 \qquad \text{Eq. 3.2}$$

The values of SS_{xy}, SS_{xx} and SS_{yy} are found as follows:

$$\text{SSxy} = \sum \text{xy} - \frac{(\sum \text{x})(\sum \text{y})}{\text{n}} = 3{,}594{,}985 - \frac{8460\text{x}5022}{12} = 54{,}475 \qquad \text{Eq. 3.3}$$

$$\text{SSxx} = \sum \text{x}^2 - \frac{(\sum \text{x})^2}{\text{n}} = 6046400 - \frac{71{,}571{,}600}{12} = 82{,}100 \qquad \text{Eq. 3.4}$$

$$\text{SSyy} = \sum \text{y}^2 - \frac{(\sum \text{y})^2}{\text{n}} = 2{,}158{,}470 - \frac{5022\text{x}5022}{12} = 56{,}763 \qquad \text{Eq. 3.5}$$

$$b = \frac{\text{SSxy}}{\text{SSxx}} = \frac{54{,}475}{82{,}100} = 0.6653 \qquad \text{Eq. 3.6}$$

$$a = y - bx = 418.5 - 0..6635 \times 705 = -49.26 \qquad \text{Eq. 3.7}$$

Therefore the estimated regression line is given by

$$y = -49.26 + 0.6635x \qquad \text{Eq. 3.8}$$

This gives a relationship for number of customers and the amount of electricity used in our data range. The scatter diagram and the regression line is shown in figure 3.1.

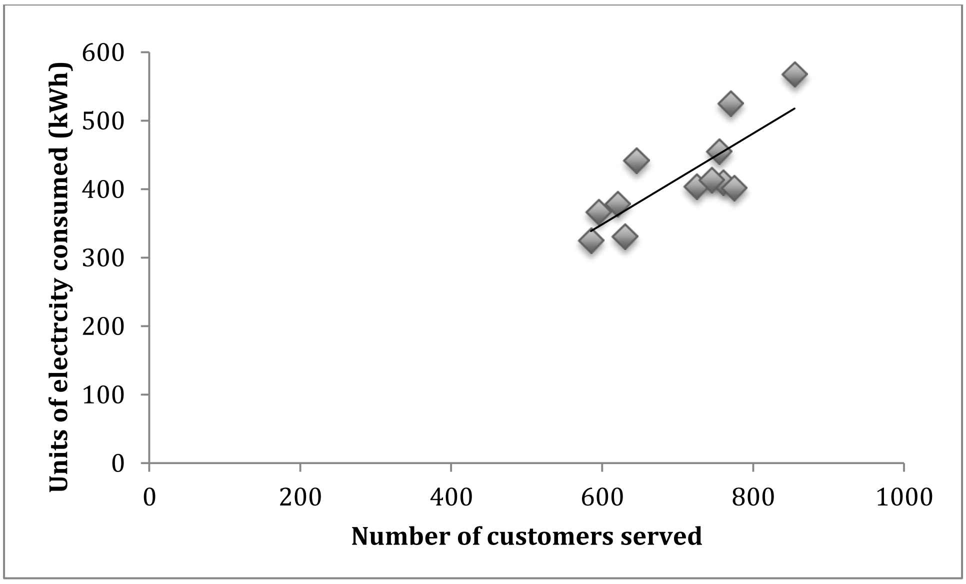


Figure 3.1. Regression line for the number of customers saved and units of electricity consumed.

The values of r and r^2 can be computed as follows:

$$\boldsymbol{r} = \frac{\text{SSxy}}{\sqrt{\text{SSxx SSyy}}} = \frac{54{,}475}{\sqrt{(82{,}100\text{x } 56{,}763)}} = 0.79798 \qquad \text{Eq. 3.9}$$

$$\boldsymbol{r^2} = \frac{\boldsymbol{b}\text{SSxy}}{\text{SSyy}} = (0.6653) \times \frac{54{,}475}{56{,}763} = 0.6384 \qquad \text{Eq. 3.10}$$

The value of r indicates that a weak positive relationship between the number of

customers served and the units of electricity consumed.

Using the regression line in Eq. 3.8

$$y = -49.26 + 0.6635x$$

we can predict that if 1000 customers were served then 614.24 units of electricity would be consumed. When figure 3.1 is examined then visual observations agree with the calculated values.

It is recognized that the business has two types of costs. These are fixed costs and variable costs. Fixed costs include heating, lighting and entertainment system, which are working even when there are no customers. Throughout the year the number of customers is highly variable since the business is seasonal. The variation can account for the negative value of the intercept calculated from regression analysis. It is recognised that ideally the intercept would be a positive value as shown in Figure 3.2. This is relevant since there is direct relationship between costs and units of electricity consumed.

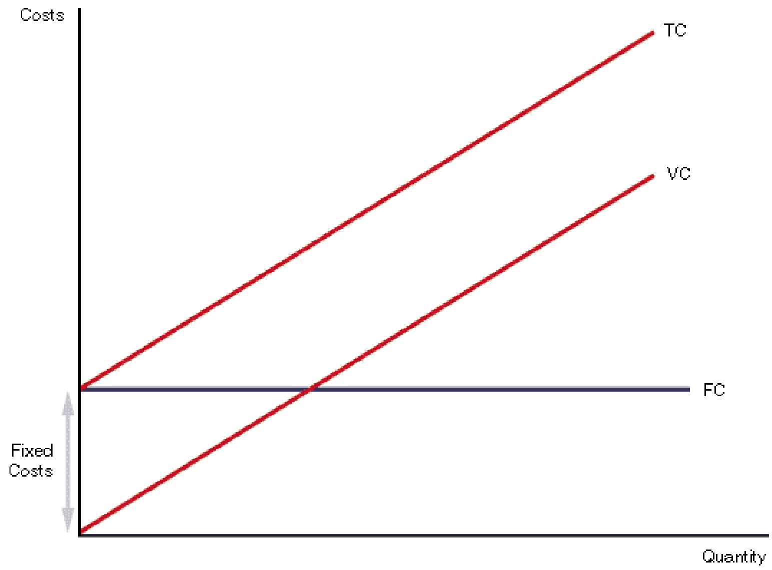


Figure 3.2. Idealized graph of fixed (FC), variable (VC) and total costs (TC).

3.3.2. Hypothesis Testing:

The following five steps were performed to test the null hypothesis (Douglas C. Montgomery, 2012)

1. The null hypothesis was stated.

H0: B=0 (B is not positive).

H1: B >0 (B is positive)

2. The t distribution was selected to make the hypothesis test.
3. The rejection and non-rejection regions were determined. The significance level was chosen as 0.05. For 6 degrees of freedom the critical value for t at 0.05 for 6 degrees of freedom is 1.812.

4.

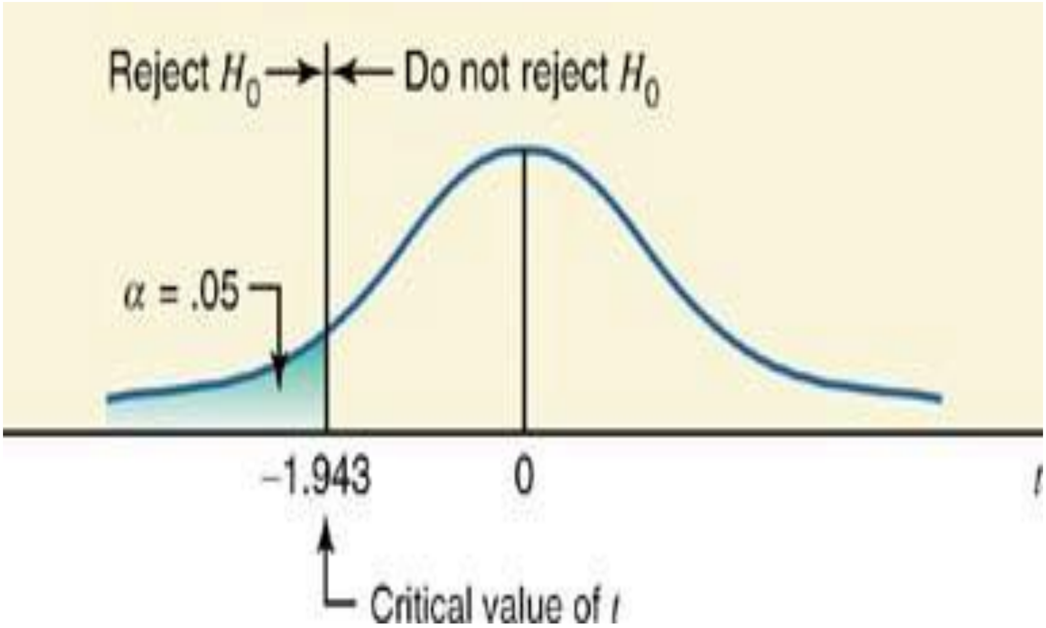


Figure 3.3. Adapted from: www.me.emu.edu.tr/hacisevki.

5. The value of the test statistic was calculated.

The value of b was calculated as follows:

$$t = \frac{b - B}{s_b} = \frac{-1.5476 - \overset{\text{From } H_0}{0}}{.5270} = -2.937 \qquad \text{Eq. 3.11}$$

6. A decision was made

The value of the t statistic falls in the rejection range and therefore we reject the null hypothesis.

CHAPTER FOUR

SOLAR RADIATION, PLANT CAPACITY OF MICRO-BUSINESSES AND CO_2 EMISSION REDUCTIONS

4.1. Introduction

Solar electricity generation relies on the amount of incoming sunlight or solar radiation from the sun (Faizal et al., 2013). As this amount of solar radiation varies according to the position on the earth's surface, there is a need determine the amount of solar radiation available at the different locations on the surface of the earth. This will ultimately determine the feasibility of using of solar panels and the amount of energy available (Teke and Yıldırım, 2014).

A comparison has been carried out on the average amount of solar radiation available in the two regions, (Teke and Yıldırım, 2014) Erbil, Kurdistan, Iraq and Manchester, United Kingdom that are under consideration in our case studies in subsequent chapters. Once the amount of solar radiation is known then further analysis on the output energy available from the solar panels can be determined and an estimate of the plant capacity can be made (Liu et al., 2014).

Two types of solar radiation sources area available for data at the earth's surface which are ground measurements and calculations which based on satellite data (Badran et al., 2010), solar radiation for ground measurement, the most widely instrument use is the (Pyranometer) which is mean all radiation the instrument measures coming from the sun and cloud (Ashhab et al., 2013). Ground measurements provide the best results.

The solar radiation estimation from satellite uses a number of methods to calculate and estimate solar radiation for ground measurement. These use the data from satellites, this type of measurement is measuring the light (visible or infrared) which come from the earth (Huld T., 2012). This light comes from the reflection light from earth or cloud, therefore while doing the solar calculation and measurement need to take into account the radiation that is reflected by the atmosphere and clouds. There are also different types of satellites measurement to estimate solar radiation (Šúri M., 2005).

It's very important to understand in the design system of PV the availability of amount sunlight at particular location at a given time. There are two common methods, which characterize the radiation of solar. They are solar radiance (radiation) and solar insolation. The solar radiance is a direct power density in kW/m^2. It varies during the day from 0 kW/m^2 at night to the highest at 1kW/m^2, indicating that solar radiance depends on local temperature of weather and the location. Solar radiance is measured using either a pyranometer, which gives the global radiation or pyrheliometer, which gives direct radiation).

The mean of solar insolation is the total solar energy amount received at a particular location throughout a specified period of time, usually given in kWh/m^2/day units. Solar insolation is the direct solar irradiance average over a period of time. Solar insolation data is normally used for simple system designs of PV while solar radiance is used for much more complicated system design of PV performance, which calculate performance at many points in a day. Solar insolation also can be measured in MJ/m^2 units per year (Díez-Mediavilla et al., 2013).

4.2. Solar Irradiance

Using Photovoltaic geographic Information System (PVGIS) solar irradiance at different locations can be seen. (Marcel Sˇu´ri *, 2007). Table 1 shows for a typical day in June the direct normal irradiance at different times of the day. Figure 1 shows this output graphically and as can be seen this irradiance fluctuates and varies throughout the day from a minimum to maximum value. Data was obtained from solar radiation database PVGIS-CMSAF.

Time:	6:07	7:07	8:07	9:07	10:07	11:07	12:07	13:07	14:07	15:07	16:07	17:07	17:52
DNI:	410	587	697	766	809	831	837	827	800	752	674	551	410

Table 4.1. Time and direct normal irradiance (W/m^2) in Erbil, Kurdistan, Iraq

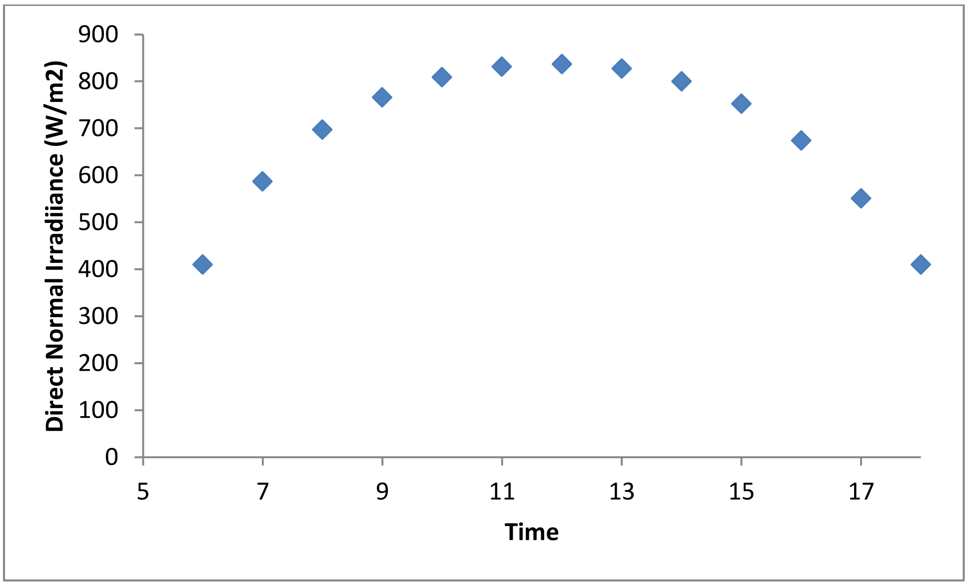


Figure 4.1 Variation of solar radiation in a typical day in Erbil, Northern Iraq in June

4.3. Cell efficiency

The output from the solar panels determines the amount of available electrical energy from the panels and this is improving continuously with developments of new technologies. Analysis can be done to show the potential output efficiency from a cell using available experimental data (Genwa and Sagar, 2013).

The sunlight impinging on the panels, i.e. irradiance or insolation (incoming solar radiation), is measured in units of watts per square meter (W/m^2). The available power output (W) from the photovoltaic module given the input solar radiation needs to be calculated and this is estimated using data from experiments with some statistical analysis based on linear regression (Genwa and Sagar, 2013).

The goal of linear regression is to produce a line that fits observations. This can be done by minimizing the squared deviations of the observed points from that line.

$$S = \sum_{i=1}^{n} d_i^2 \qquad \text{Eq. 4.1}$$

where d_i is the i^{th} residual associated with the n data points.

When a regression line has been found, it can be used to predict a value of the dependent variable. There are some fundamental assumptions in linear regression analysis that are studied in order to consider the analysis is properly executed. There needs to be a linear relationship between the independent and dependent variables. The residuals can be considered to be normally distributed and that the calculated values are consistent with observed values.

4.4. Effect of temperature on solar panel output

It is important to note that the temperature also affects the amount of energy produced by solar cells (Skoplaki and Palyvos, 2009). When the temperature is increases as is the case when we compare UK to Northern Iraq particularly in the summer the solar cells become less efficient hence the amount of electricity produced is reduced. The efficiency of the solar cells is dependent on the amount of power produced when light shines on it. The efficiency can be measured by illuminating the solar panel with a calibrated light sources and measuring the amount of current produced at different voltages (Radziemska, 2003). Hence, the current as a function of the voltage can be plotted. The power produced can be calculated using the current and voltage. This is done as follows:

$$P = J \times V$$

where P is the power produced, J is the current and V is the voltage.

The power is plotted in figure 4.2 with the maximum value occurring along the current-voltage curve. This represents the maximum power and used to calculate the efficiency given by

$$\eta = \frac{Imax \times Vmax}{Pin} \qquad \text{Eq. 4.2}$$

where η is the efficiency, I max is the current at the maximum power point, Vmax is the voltage at the maximum power point and the P is the power incident to the radiation on the solar cell.

This equation can be rewritten as follows:

$$\eta = \frac{Isc \times Voc \times FF}{Pin} \qquad \text{Eq. 4.3}$$

where *Isc* is the current at short cicrcuit (*V*=0), *Voc* is the voltage at open circuit (*I*=0) and *FF* is the fill factor.

When the temperature increases and solar cells get hot the current increases and the voltage decreases and since the voltage decreases faster than the current the efficiency decreases. Hence

$$\eta\downarrow = Isc\uparrow \times Voc\downarrow \times FFPin \qquad \text{Eq. 4.4}$$

Even though the performance of the solar depends on the temperature the effect is small and the panels will function well even in the higher in Kurdistan in the summer(Coventry, 2005). Therefore, whilst recognizing that solar performance degrades at higher temperatures this effect will not be considered due to it being small compared to the overall impact of amount of sunlight in UK and Kurdistan and it is assume that the performance will be maintained (Papageorgiou et al., 1996).

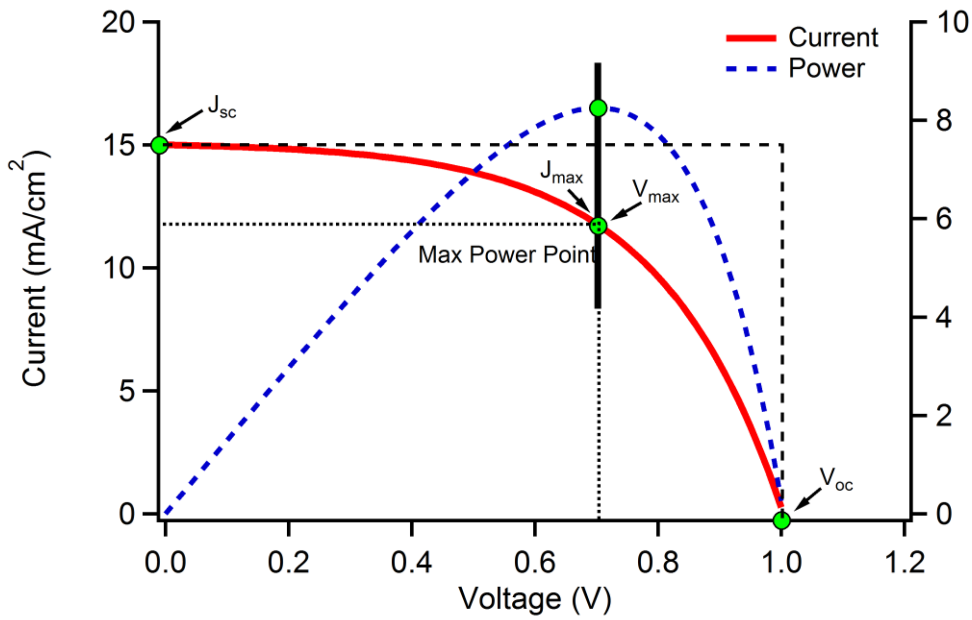


Figure 4,2. Voltage-current curve for solar cells. Adapted from: (http://www.digikey.com)

4.5. Solar radiation and power output from solar cells

To calculate the relationship for the solar radiation available on the tilted surface and the energy output of the PV generator, data from a photovoltaic module BP SX PV was used [14], see Table 4.2 below:

Solar Radiation $(\boldsymbol{W/m^2})$	**Power** $(\boldsymbol{W})$
0	0
400	55
600	85
800	120
1000	150

Table 4.2. Solar radiation and power

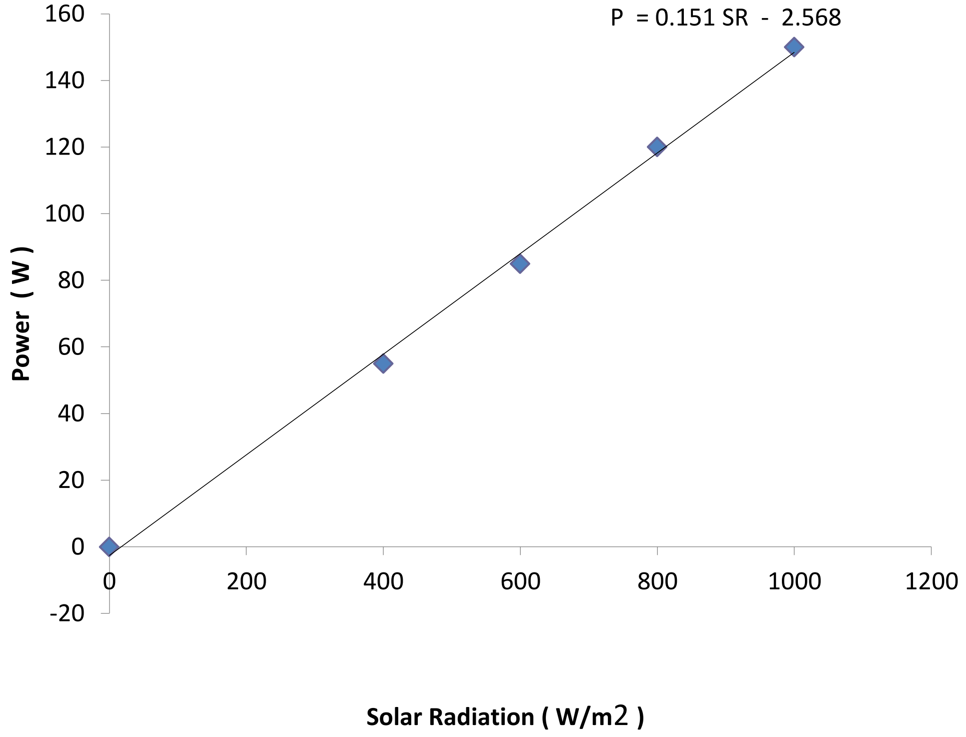


Figure 4.3**.** Relationship between solar radiation against power output

Figure 4.3 shows the line of best fit for the above data from which the following relationship is obtained.

$$\boldsymbol{P = 0.151\,SR - 2.568} \qquad \text{Eq. 4.5}$$

This equation gives an effective power output for a photovoltaic module given solar radiation input and is used in subsequent sections enabling calculations of power outputs to be made.

4.6. Calculation of potential output solar energy using panels of fixed dimensions in Erbil

Since for our solar system design we need solar insolation, we can use data available for Erbil, Kurdistan, Iraq, as seen in Table 4.3.

Month	**Wh/m^2/day insolation**	**Daily PV Output Wh/m^2 (15.1%)**
Jan	3690	557.19
Feb	4160	628.16
Mar	5120	773.12
Apr	5460	824.46
May	6060	915.06
Jun	6620	999.62
July	6520	984.52
Aug	6510	983.01
Sep	6320	954.32
Oct	5120	773.12
Nov	4110	620.61
Dec	3470	523.97
Total	**63160**	**9537.16**

Table 4.3**.** Solar Insolation average for each month and the possible output for Erbil

Figure 4.4 below shows the same data graphically and as expected the summer months show peak values and the winter months showing minimum values.

Using our relationship for solar radiation and power output, calculations for the output from the PV module can be made and are shown graphically in Figure 4.4 below.

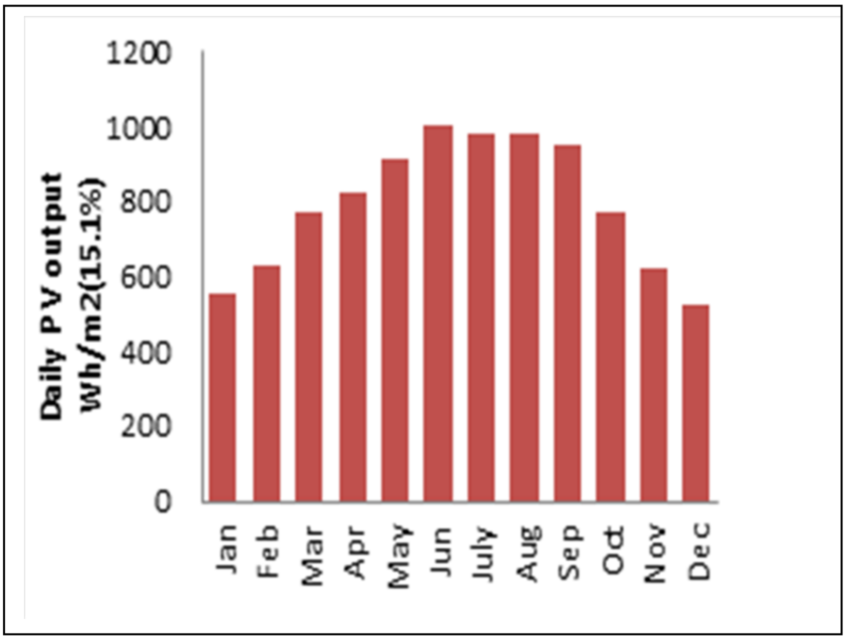


Figure 4.4. Daily PV output for each month in Erbil

4.7. Potential solar output from 6 m^2 solar panels in Erbil

Using the data from Table 4.3, calculations can be made to estimate the possible plant output for Erbil in Kurdistan, Iraq.

Calculation	Output
Average output per day $Wh/m^2/day$	794.76
Average output per day per $6m^2$ area	4.8 kWh/day
Annual average output per $6m^2$ area	1.74 MW/year

Table 4.4. Possible plant output in Erbil, Kurdistan, Iraq

4.8. Calculations for 6m^2 solar panels in Manchester, U.K

A similar analysis to that carried for Erbil, Kurdistan, Iraq can be done for a micro-business in Manchester and with a different climate and less solar insolation available we expect lower output power.

Month	Wh/m^2/day insolation	Daily PV Output Wh/m^2 (Efficiency 15.1%)
Jan	1110	167.61
Feb	1950	294.45
Mar	2830	427.33
Apr	3960	597.96
May	4880	736.88
Jun	4760	718.76
July	4720	712.72
Aug	4180	631.18
Sep	3270	493.77
Oct	2150	324.65
Nov	1270	191.77
Dec	870	131.37
Total	**35950**	**5428.45**

Table 4.5. Solar radiation in 2013 in Manchester, UK

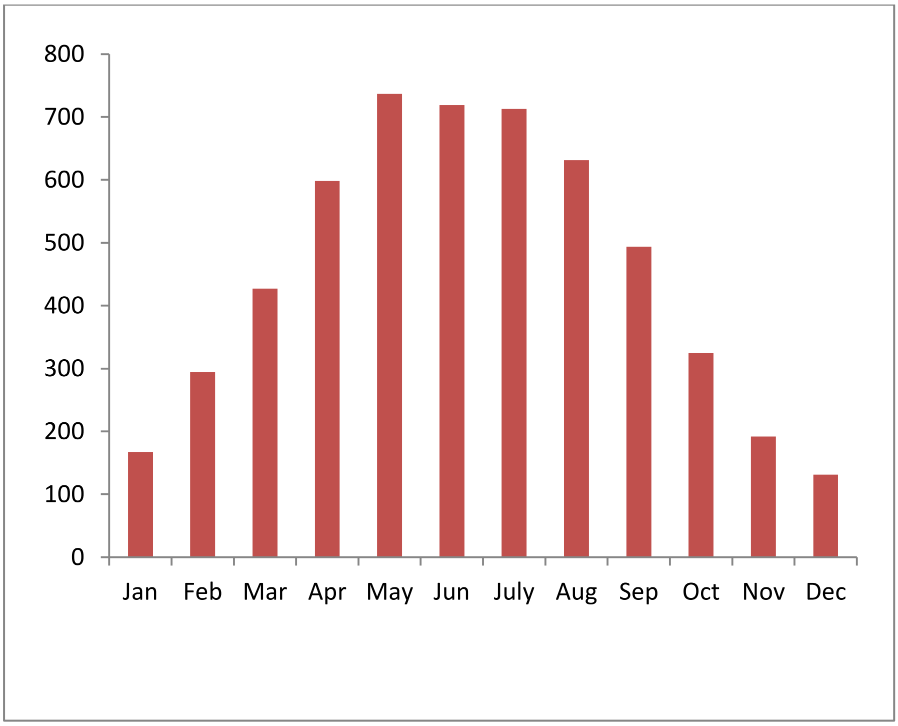


Figure 4.5. Daily solar insolation for each month in Manchester

Calculation	**Output**
Average output per day Wh/m^2/day	452.37
Average output per day per 6m^2 area	2.7 kWh/day
Average output per year per 6m^2 area	0.99 MW/year

Table 4.6. Electricity output from solar cells in 2013 in Manchester, UK

The calculations show that the output potential using solar panels is much higher in Kurdistan, Iraq than in the U.K as expected due to the hotter climate and sunnier conditions in Kurdistan, Iraq. We see that in Kurdistan we can expect 75% more energy output using a micro-business with a fixed available area space than the same business operating in the U.K.

4.9. Cost analysis of a photovoltaic solar panel system connecting a grid system

With the energy potential from using solar panels for the micro-business in Northern Iraq and the U.K being established in the previous sections, it is important to know the associated costs of implementing such systems in both of the countries. The specifications for the equipment needed are based on the availability of the components within the region. The generation system of Grid interconnection for photovoltaic (PV) power has the advantage of effectively utilizing the power generated. However, the technical needs of the system of the utility power grid and the PV system requires a guarantee of PV installer safety and the utility grid reliability (Li et al., 2009).

To carry out the cost analysis for a grid connected solar photovoltaic plant in Erbil, Kurdistan, Iraq and Manchester, U.K, the amount of solar irradiation during the months of the year and over the whole year has to be estimated. This data was utilized in our previous sections and assuming that the effective solar energy is available for approximately six hours during the day. The output power available for utilization depends on the efficiency of the PV modules used. Previous analysis showed that efficiency values of 15.1% can be taken currently with different types of PV modules. A grid connected photovoltaic system is designed with the components available for the estimated capacity from the fixed chosen available area. Using equipment available in the region a method of design is presented. The cost analysis can be carried out once the required KW per day is known using the following methodology. If we apply the above method to our micro-business in Kurdistan, Iraq and in Manchester, U.K we can arrive at an approximate cost for the different energy outputs.

Table 4.4 gives the average output per day per 6 m^2 area to be 4.8 kWh/day which is approximately rounded to 5kWhr/day. Division by the area gives 5kWh/day divided by

6m^2 gives 833 Wh/day/m^2 and this approximately 830 W output per m^2 as used in table 4.7. Similarly in the UK from table 4.6 the average out per from 6 m^2 is 2.7 kWh/day which about 3kWh/day hence division by the area give 500 W output per m^2. These values have been used in table 4.7 for a comparative analysis of Uk and Kurdistan Iraq. The values for P have been calculated as follows: 830W/150W gives a value of 5.5 ≈ 6 and 500W/150W gives 3.33 thus requiring 4 panels ie P=4.

Estimate Cost for a fixed (A) W Solar PV System

		Kurdistan, Iraq A = 830 W	**U.K A = 500 W**
Solar Panels	Price of solar panel = £ 0.95/watt Use 150W panels, P: no. of panels Cost, £ 0.95 x 150 x (P) =	P = 6 £0.95x150x6 = £855	P = 4 £0.95x 150x4 = £570
3-φ Inverter	One piece for (A) W inverter unit Price is £ 0.25/watt Cost , £ 0.25 x (A) =	£0.25 x 830 = £ 207.5	£0.25 x 500 = £ 125
3-φ step-up Transformer	One piece for (A) W. Price is £ 0.20/watt Cost, £ 0.20 x (A) =	£0.20 x 830 = £ 166	£0.20 x 500 = £ 100
Subtotal	**£ (B)**	**£ 1228.5**	**£795**
Extra system requirements (switches, wires etc.)	Multiply by 15% (0.15) Cost, £(B) x 015 =	£1228.5 x 0.15 = £184.28	£795 x 0.15 = £119.25
Total Estimate	**£ (C)**	**£ 1412.78**	**£ 914.25**

Table 4.7. Calculations of costs of solar panels in Iraq and UK

These figures are estimates since the actual prices may vary over time and there may be component price variations between the two countries (Vafaeipour et al., 2014). These figures indicate that such systems could be implemented in the chosen micro-business in both countries at reasonable investment costs (Marini et al.).

4.10. Analysis of CO_2 emission reductions

The steady increase in the earth's temperature in the last three decades highlights how global warming has increasingly become a major concern for the future of our planet (Kamal, 1997). To meet the world's needs for low CO_2 power generation, alternatives to conventional use of fossil fuels are required (Khalil, 2008). Solar energy is an alternative that represents a vast resource that can be harnessed in all regions of the world. Greater dependency and the use of fossil fuel to generate electricity to match the rapid power demand due to technological developments and increasing population have resulted in huge pollution and damage to the environment.

Energy generation and the impact it has on the climate can be characterised by its carbon emission intensity i.e. a measure of the CO_2 or other greenhouse gases such as methane CH_4 or nitrous oxide N_2O, which are released into the environment. Figure 4.6 shows how gases have been increasing over time.

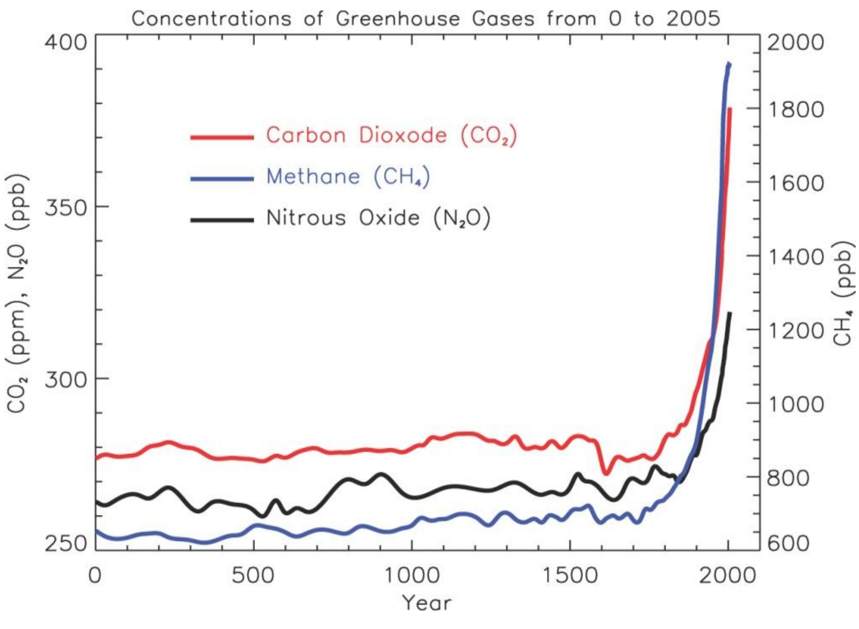


Figure 4.6. Concentration of Greenhouse Gases over the last 2000 years. Adapted from: www.nca2009.globalchange.gov/2000-years-greenhouse-gas-concentrations

Global warming and the rise in the earth's temperature over the years have been gradually rising as seen in Figure 4.7.

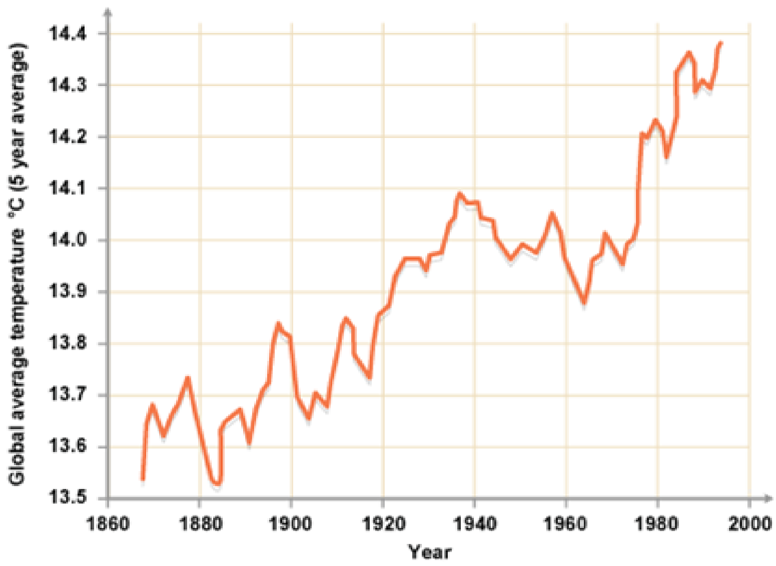


Figure 4.7. Global average temperature of the earth. Adapted from: www.bbc.co.uk/schools/gcsebitesize/science.

A comparison of the amount of carbon emission intensity produced from different technologies is shown in Figure 4.8 [4].

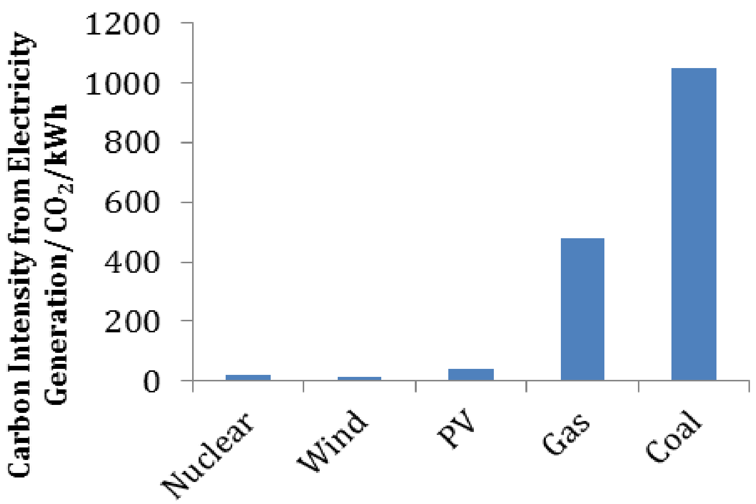


Figure 4.8. Carbon emissions for energy sources. Adapted from: www.cgge.aag.org/GlobalClimateChange

It can be seen from the above figure that renewable technologies produce little or no emissions during operation but can produce some emissions during the manufacturing phase.

A comparison can be made in relation to the amount of harmful CO_2 emissions that can be reduced if conventional fossil fuel is replaced by solar energy.

4.10.1. CO_2 reductions for the micro-business in Iraq and U.K

The amount of CO_2 emissions actually reduced is a function of the amount of conventional power being displaced (Smith, 1993), its carbon intensity and on the amount and type of energy that is consumed in the manufacturing and set up of solar energy plant (Khalil, 2008).

From the calculations in section 4.5 and 4.6 an estimate for the amount of electricity produced annually from a typical micro-business with an available $6m^2$ area space by using solar energy can be made and then an estimate for the corresponding CO_2 reductions are possible.

Determining the carbon footprint of one kilowatt-hour of electricity produced by the different methods is not exact, using as many life-cycle analyses, an average value for the different methods can be obtained as shown in table 4.8.

	Coal	**Solar/PV**
UK	0.43	0.105
Kurdistan, Iraq	0.52	0.105

Table 4.8. CO_2 released for 1kWh produced by some power generation methods, kilograms CO_2/kWh

Taking the average values for the CO_2 emissions for Coal gives 0.43 kg CO_2 /kWh and for Solar (PV) gives 0.105kg CO_2/KWh. From these values an estimation of the reduction in CO_2 emissions can be made.

	Kurdistan, Iraq	United Kingdom
Electricity (kWh/year)	1473.6	828.9
Fossil Fuel CO_2 emissions, (kg)	766.3	356.4
Solar PV CO_2 emissions, (kg)	154.7	87.0
Total Reduction in CO_2 emissions (kg)	611.6	269.4

Table 4.9. Comparison of CO_2 reductions for a micro-business in Kurdistan, Iraq and the U.K

The above table shows the figures for the amount of carbon dioxide emission reduction is possible from a typical micro-business. If we sum all such businesses in the countries say approximately around four and half million similar micro-businesses then we see that the amount of CO_2 reductions is huge.

Region	**Calculation**	**CO_2 (kg)**
Kurdistan, Iraq	611.6 x 4,500,000	2752,000,000
United Kingdom	269.4 x 4,500,000	1212,300,000

Table 4.10. Amount of CO_2 released from equivalent micro-businesses in Kurdistan, Iraq and UK

4.10.2. CO_2 reductions from Sulaymanyah Airport

Micro-businesses can have huge impacts on the CO_2 emission reductions we can now compare these with a larger airport facility in Kurdistan, Iraq and see what kind of impact this can make on the environment (Broberg Viklund and Johansson, 2014).

Sulaymanyah Airport energy usage and CO_2 prevention has been analysed. This Airport is located in Northern Iraq and it is 15 km outside the city of Sulaymanyah, in the Kurdistan rejoin. The airport has facilities for both passengers and cargo services. The airport has three terminal, which are arrivals, departures, and VIP. The construction of the airport began by Kurdish Region Government in November 2003, and it was inaugurated in July 2005.

In this study the operation and electricity demand of the airport has been analysed. A solar energy plant which can supply around 7.3% of the airports electricity demand will be considered with approximate set up costs. Cost analysis of such a plant in the region has been carried out previously (K. Khan. W. Ahmed, 2014). Analysis of the cost benefits and CO_2 emission reductions using the solar plant can now be considered. The amount of CO_2 emissions actually reduced is a function of the amount of conventional power being displaced, its carbon intensity and on the amount and type of energy that is consumed in the manufacturing and set up of solar energy plant.

4.11. Insolation and energy output

Solar insolation for the Northern Iraq region varies throughout the year and the total energy output for an available area to generate a 315 KW solar plant shown in Table 4.11.

Month	Energy output (KWh/month)
Jan	40574
Feb	41314
Mar	56298
Apr	58100
May	66634
Jun	70444
July	71691
Aug	71581
Sep	67252
Oct	56298
Nov	43734
Dec	38155
Total	**682075**

Table 4.11. Monthly and total energy output using available area for the plant in Kurdistan, Iraq

Below is the graph showing the total energy output for the plant.

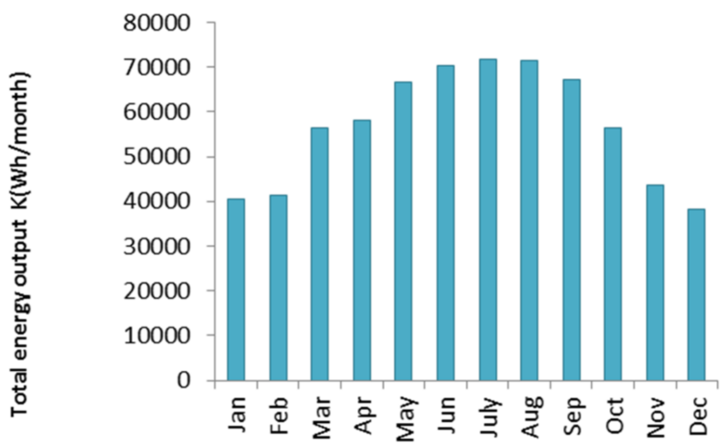


Figure 4.9. Total energy output for available area

The international airport electricity consumption demand and costs are shown in table 4.11 below.

Month	Unit (kWh)	Cost (£)
Jan	745158	11400.92
Feb	800428	12246.55
Mar	619136	9472.78
Apr	561406	8589.51
May	650623	9954.53
Jun	915408	14005.74
July	936244	14324.53
Aug	1036399	15856.90
Sep	916440	14021.53
Oct	705736	10797.76
Nov	771288	11800.71
Dec	717955	10984.71
Total	**9,376,221**	**143,456.17**

Table 4.12. Monthly energy consumption and its costs for Sulaymanyah Airport

Figure 4.10 and 4.11 show the graphs for the energy demand and cost of the energy at Sulaymanyah International Airport respectively.

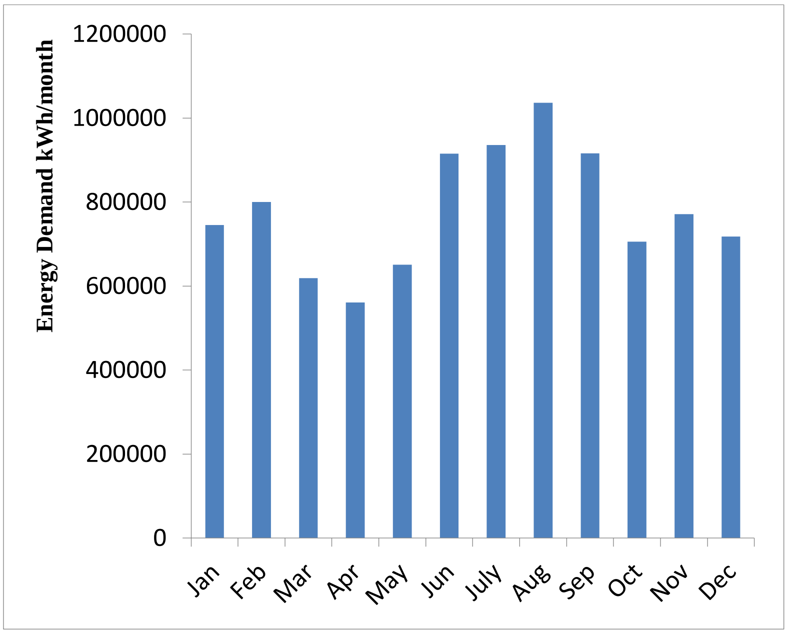


Figure 4.10. Energy consumption at Sulaymanyah airport

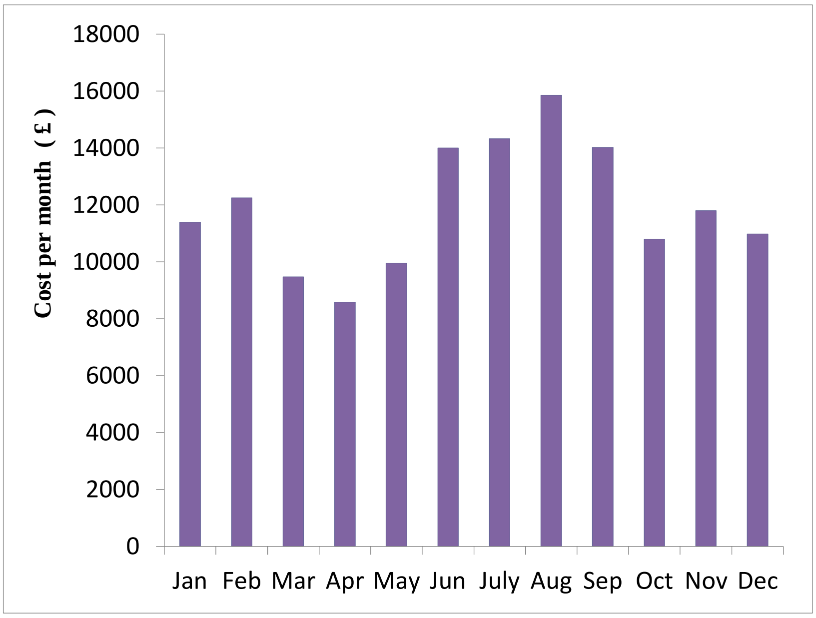


Figure 4.11. Cost of electricity at Sulaymanyah Airport

A 315 KW solar energy plant could make available

$$\frac{682075 \quad kWh}{9376221 \quad kWh} \times 100 = 7.3\ \% \qquad \text{Eq. 4.6}$$

This amount of conventional fossil fuel energy for the airport could be replaced by solar energy using photovoltaic cells and hence corresponding reductions on CO_2 emissions can be estimated for this region. Determining the carbon footprint of 1 kWh of electricity produced by the different methods is not exact, using as many life-cycle analyses, an average value for the different methods can be obtained as shown in table 4.13.

Energy Production	**CO_2 emission (kg)**
Fossil Fuel	682075 x 0.52 = 354679
Solar Photovoltaic	682075 x 0.105 = 71617.88
Total Reduction	**283,061.12**

Table 4.13. CO_2 emissions reductions for Sulaymanyah Airport

If this result, from table 4.13, is multiplied by a factor twenty, which represents the average lifespan of solar cells in years then 5.6 million kg of CO_2 emissions can be prevented from entering the atmosphere hence reducing the harmful effects on the environment.

4.12. Conclusions

Kurdistan has a good number of sunshine hours a day throughout the whole year and is ideal place to harness the solar energy. A micro-business both in the U.K and Kurdistan, Iraq has potential for replacing some proportion of its electrical energy needs by the use of solar energy. If all such micro-businesses are taken into account then it was shown that significant harmful carbon reductions could be made to the environment both in the U.K and more so in Kurdistan, Iraq. A solar plant with a capacity to generate around 7.3% of the airport's yearly demand was found to have a potential to reduce the carbon dioxide emissions by 0.28 million kilograms a year. Considering this over a period of the average life span of a solar photovoltaic system of twenty years, gives rise to huge saving in CO_2 emissions in the region of 5.6 million kilograms. These reductions will only occur if initial investment costs of setting up such a plant are incurred, however over the average life span of the solar plant almost half of the initial costs would be recovered. Use of multiple solar plants throughout the whole country would start to make significant impacts on overall CO_2 emissions. Although other renewable energy sources have very low CO_2 emissions, the use of solar energy is a more viable option in certain remote regions as well as in developing countries as these systems can be set up as stand-alone operations without the need for a national grid structure. With the challenges that the world faces due to global warming there is a urgent need to use alternative sources of energy that do not have adverse effects on the earth's atmosphere. With continuous reduction in costs and increasing efficiencies in solar PV technology this method of energy generation has huge potential both for being environmentally friendly and as an energy source for SME's and larger facilities like airports.

CHAPTER FIVE

ENERGY AND CARBON DIOXIDE ANALYSIS OF GROOM GENTS HAIRDRESSING SALON

5.1. Introduction

This chapter focuses on a small business in the service sector, Groom Gents Hairdressing Salon, which can be classified as an SME type of businesses and a small public business. It is a single component of multiple component system such as a business found on the high street, mall, plaza or shopping complex (Scarpellini and Romeo, 1999). This business is solely reliant on electricity supply originating from fossil fuels. Data has been collected over for a period of one year from components using electricity. The power rating and utilisation time were noted. The data was analysed using commercially available computer program MATLAB and EXEL. A relationship between electrical power used and the CO_2 emission generated by this SME were established (Al-Ghandoor et al., 2013). The CO_2 contribution emanating from such an SME was calculated and compared between UK and Iraq. The feasibility of replacing fossil fuel sources in UK and Iraq for such a small business with existing silicon solar cells and future generation of organic solar cells employing state of the art nanotechnology was explored.

For a comparison between UK and Iraq in a typical hair salon business using was studied. The electricity utilisation by each component was considered. In the UK the electricity bill is consistent and transparent. It is therefore simple to see how much electricity has been used and the cost associated with each unit. In Iraq the electricity cost is highly subsidised by the Government and is not a true reflection of the actual costs. Therefore, measurement and analysis for individual components using electricity was carried out. The CO_2 contribution from electricity used by each component was calculated. The power rating and utilisation time for individual components were noted during various hairstyles. MATLAB was used in this study to plot graphs and analyse data. This involved calculations of mean, standard deviation and various curve fitting done.

5.2. Results and discussion

5.2.1 Energy consumption and business analysis in 2012

To obtain an overall picture of the Groom Gents Hairdressing measurements were taken over the year 2012. These are summarised in table 5.1

Month	No of days open	Units consumed (kWh)	No of customers served	Cost of electricity (£)
Jan	25	331	630	66.20
Feb	25	379	620	75.80
Mar	27	442	645	88.40
April	24	325	585	65.00
May	27	367	595	73.40
June	26	404	725	80.80
July	26	455	755	91.00
Aug	26	410	760	82.00
Sept	24	402	775	80.40
Oct	27	414	745	82.80
Nov	27	525	770	105.00
Dec	23	568	855	113.60
Total	**307**	**5,022**	**8,460**	**1,004.40**

Table 5.1. Basic electricity/energy data for the business in 2012

For a service business to be viable it must be accessible to customers and this has implications for energy utilisation during its operation. Therefore, data was collected for the opening days during a calendar year 2012. The number 1 represents January and February by 2 and so on with 12 represents December. The salon closed on Sundays and bank holidays and an extended break during Christmas and New Year.

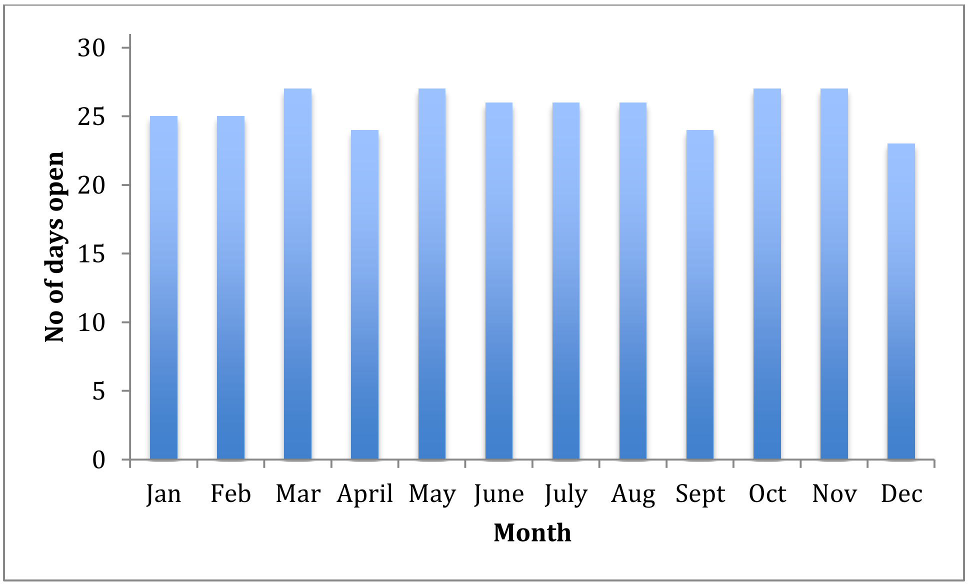


Figure 5.1. Number of days the salon is open during 2012 by month

The statistical analysis of the data using MATLAB gives the following:

Parameter	Value
Minimum	23
Maximum	27
Mean	25.58
Median	26
Mode	27
Standard deviation	1.379
Range	4

Table 5.2. Statistical analysis of the opening days in 2012

The number days open ranged from 23 to 27. In March, May, October and November the salon was open for 27 days with these months having 31 days. Most of the year the salon was open for 27 days as indicated by the mode with the range being 4 days over the year and standard deviation of 1.38.

The variation in the monthly units consumed was also analysed. Intuitively the variation in monthly units consumed is expected to mirror the opening times when the business is conducted. The data is plotted in figure 5.2.

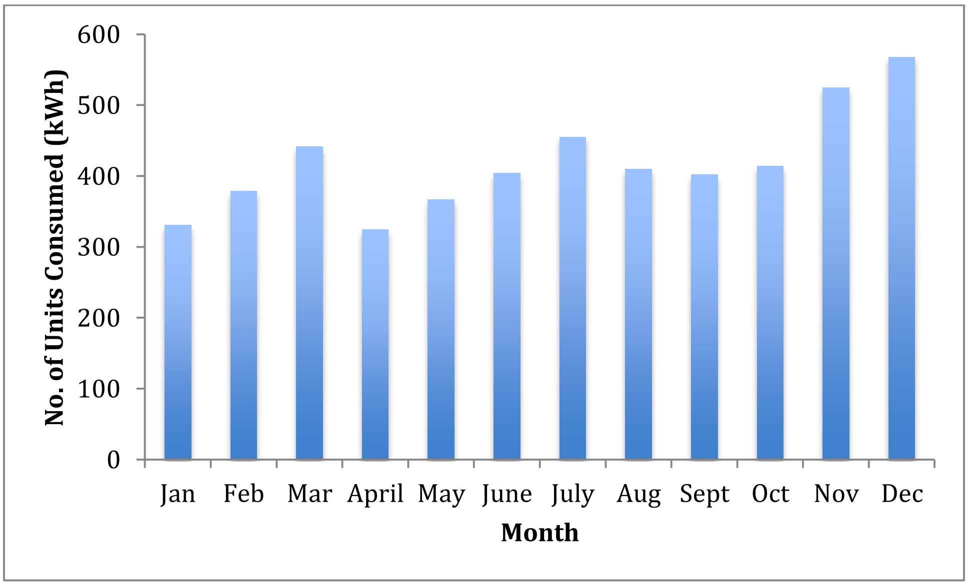


Figure 5.2. Number of units consumed during the months in 2012

Visual examination shows that figure 5.1 and 5.2 do not follow similar trends as predicted. For example, the salon is open the least number of days in December and more units are of electricity are used. The data was analysed using MATLAB and shown in table 5.3.

Parameter	**Value**
Minimum	325.0
Maximum	568.0
Mean	418.5
Median	407.0
Mode	325.0
Standard deviation	71.8
Range	234.0

Table 5.3. Statistical analysis of the units consumed in 2012

Month	Days open	Units consumed (kWh)	Customers served	Units/day	Unites/customer	Normalised Days open	Normalised units consumed	Normalised customers
Jan	25	331	630	13.24	0.53	0.9773	0.7909	0.8936
Feb	25	379	620	15.16	0.61	0.9773	0.9056	0.8794
Mar	27	442	645	16.37	0.67	1.0555	1.0562	0.9149
April	24	325	585	13,54	0.56	0.9382	0.7766	0.8298
May	27	367	595	13.59	0.62	1.0555	0.8769	0.8440
June	26	404	725	15.34	0.56	1.0164	0.9654	1.0284
July	26	455	755	17.50	0.60	1.0164	1.0872	1.0709
Aug	26	410	760	15.80	0.52	1.0164	0.9797	1.0780
Sept	24	402	775	17.17	0.52	0.9382	0.9606	1.0993
Oct	27	414	745	15.33	0.56	1.0555	0.9892	1.0567
Nov	27	525	770	19.44	0.68	1.0555	1.2545	1.0922
Dec	23	568	855	24.70	0.66	0.8991	1.3572	1.2128

Table 5.4. Normalised values of the number days open, units consumed and customers served

The number of units used per customer was calculated and showed little variation from between 0.68 to 0.52, a difference of 0.16. The number of units per day was also calculated and ranged from 13.24 to 24.7, which is a difference of about 10. In terms of costs this equates to a difference of £2.00. The price range of the hair styles range from £6.00 to £16.00. The difference is within the costs differences in the price charged for the different styles. However, the price depends on styles and another factor is the time spent on the customer by the stylist.

It is difficult to compare trends between number of days open, the number of customers served and units consumed due to large differences in numerical vales in these categories. Normalisation simply shifts the scales of the datasets so that comparisons can be made. Hence, to compare closely trends in the data for the number of days the salon is open, number of units and days salon opened were normalised against the means of values of the 3 data sets. This enables the data to be plotted onto one another on the same graph. A close relationship is indicated by the closeness of the graphs relative to one another. The normalised values to four decimal places are given.

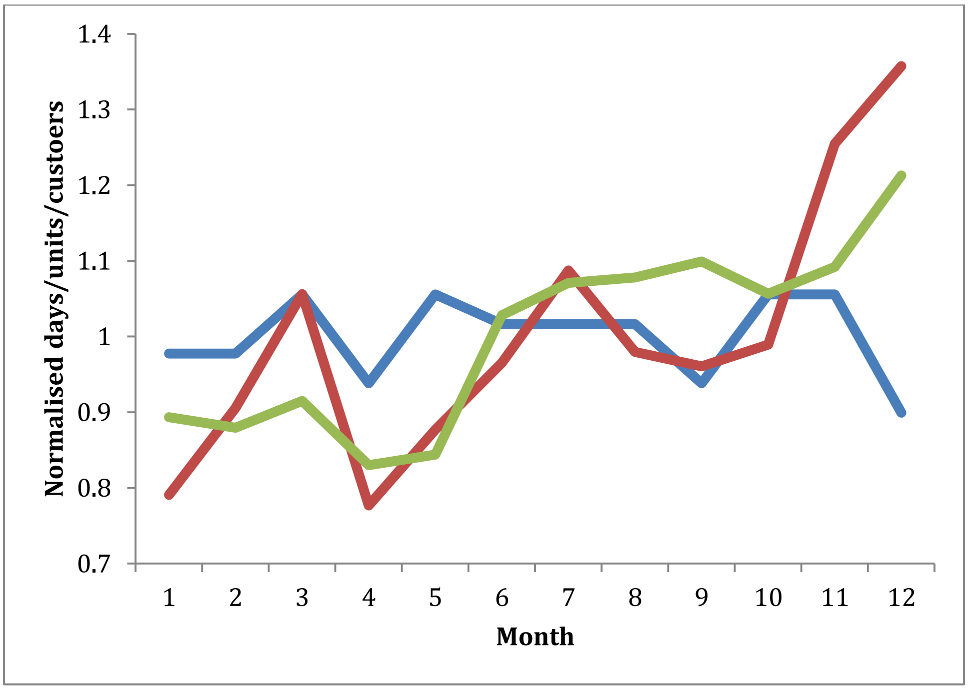


Figure 5.3 Normalised values of days salon is open (blue line), units of electricity used (red line) and number of customers (green).

It is evident from figure 5.3 that there is no direct relationship between the number of days that the salon is open and the number of units of electricity consumed. The peak units consumed occurred in March, July and December. The peaks of the two variables coincided only in March. There is s large difference between the number of days salon is open and the number of units of electricity consumed in December. The number of days the salon is open is the least and the number of units consumed is the most. Hence, it can be concluded that there is no direct relationship between the number of units consumed and number of days the salon is open.

In order to correlate the units consumed with customers the monthly variations in the customer count were studied. A close relationship exists between units consumed and number of customers. However, in September there is a discrepancy between the number of customers and units of electricity consumed. This could be due to the different types of hairstyles that the salon offers. At the beginning of September children in the UK go back to school and the trend is to get a haircut before starting the school year normally short back and sides using a small clipper and scissors which uses little electricity compared to hairdryer and wash used for more sophisticated adult styles (González-Gil et al., 2013).

Clearly, the total cost of doing business is a primary area of performance measure. The lowest energy costs were in April of £65.20 and highest in December of £133.60. It was calculated that the energy costs were only 2.12% of the other costs of doing the business. This is very small percentage and agree with researchers who suggested SME energy costs are so small that only tiny savings can be made and thus not worth the investment in energy management systems (Bala Subrahmanya, 2006).

There is a direct correlation between units consumed and the cost of energy. Each unit costs 20p. Hence a linear relationship is expected between the energy bill and units consumed. The lowest units consumed were 325 units and the highest number of units consumed was 568, with the lowest cost of electricity being £65 and the highest cost of electricity was £113.60. It should be noted that within the period of the study the electricity tariff was fixed by the energy supplier, British Gas under contract.

The relationship between number units consumed and the cost is shown in figure 5.4.

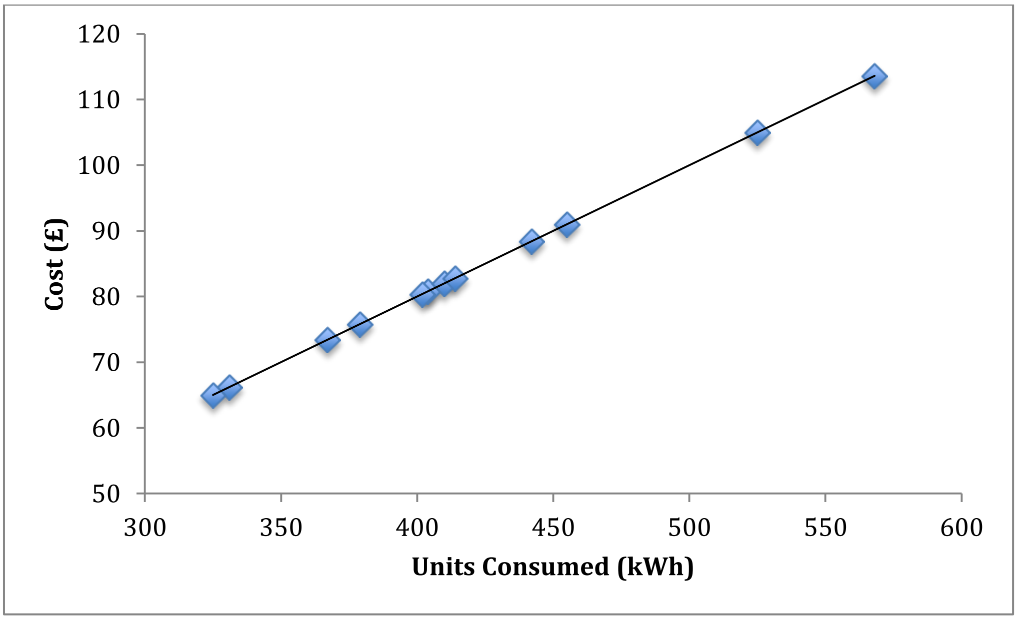


Figure 5.4. Relationship between cost and the number of units consumed

There is a strong positive linear correlation between the number of units of electricity used and the overall cost of electricity consumed is clearly evident from figure 5.4. This trend was expected since the unit cost is a fixed by the energy supplier in the UK. Using MATLAB linear curve fitting was done. A straight-line equation is given as follows:

$$y = ax + b \qquad \text{Eq. 5.1}$$

where a = 0.20147 and b = -0.64822 and the norm residuals being 0.81494.

The units consumed has been for each months also the numbers of customers been served each month, also showing that the less units been spend was 331 unites and the larger one was 568 unites, also the smallest numbers of customers been served was 620 customers and the largest number of customers been served was 855 customers.

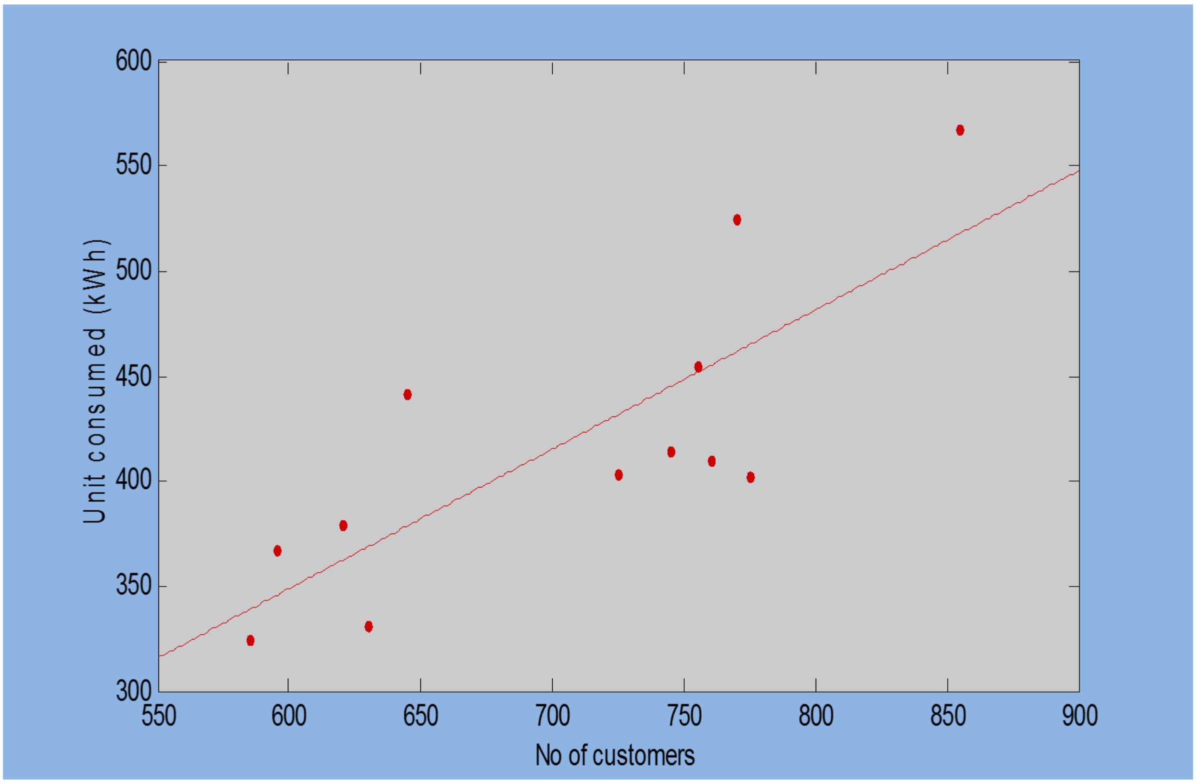


Figure 5.5. Relationship between the units and number of customers

As the number of customers increase the number of units consumed also increases as shown by the best-fit line in MATLAB. However significant deviations from the line are evident in Eq. 5.1.

with a = 0.6635 and b = -49.2825

Using MATLAB the quadratic function and cubic mathematical functions were also tested respectively to see a better fit could be obtained (see figure 5.7).

$$y = ax^2 + bx + c$$

where a = 0,0024, b = -2.7244 and c = 1129

and

$$y = ax^3 + bx^2 + cx + d \qquad \text{Eq. 5.2}$$

where a = $2.945\text{x}10^{-5}$, b = -0.061396 and c = 43.263 and d = -9817.5

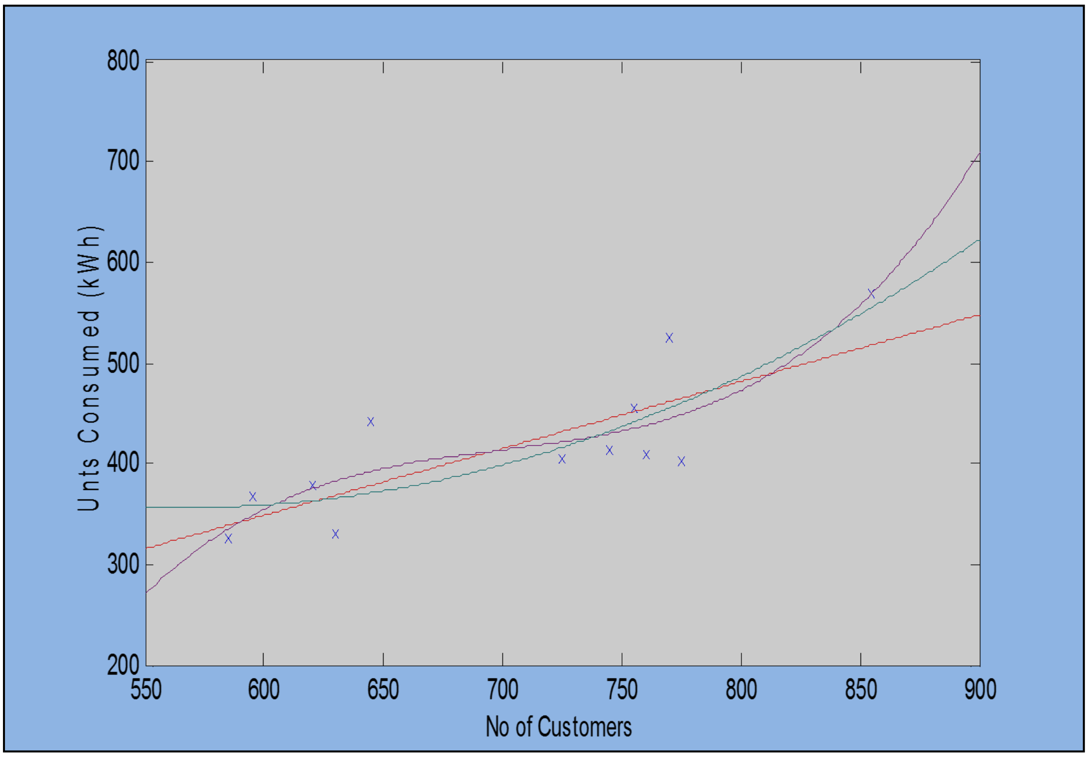


Figure 5.6. Curve fitting in MATLAB using linear (red line), quadratic (blue line) and cubic (purple line) functions for units used and customers served

The variations resulting in peaks and trough are due to the use of different types of equipment used. For example, if scissors are used for a haircut then the only electricity consumed is for heating and lighting. However, if the haircut involves wash, clippers, and hair dryer then extra electricity is used. The variation in styles explains the variations in the data between the units of electricity consumed and the number of customers.

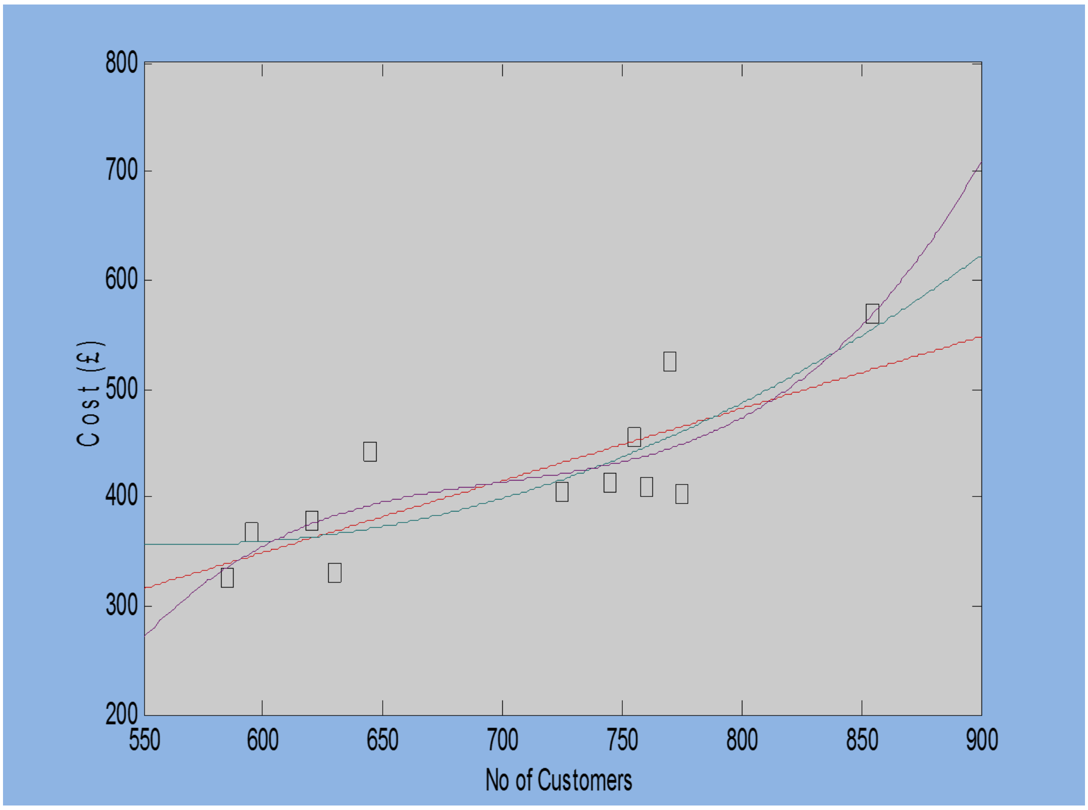


Figure 5.7 Curve fitting in MATLAB using linear (red line), quadratic (blue line) and cubic (purple line) functions for electricity cost against number of customers

There is a moderate linear correlation between the number of customers served and the electricity consumed. The local variations are due to the variety of styles requested by the customer. When the number of dry cuts is high then the amount energy used is lower as expected, however when shower & hair dryer and clipper are used more electricity is required to operate the tools needed for the desired hairstyle. The number of customers ranged from 585 to 855 and the cost from £65 to £114 with the gradient of the line being 2.70.

It should be noted that there is a base load when the business in open so there are fixed costs due to heating, lighting, entertainment and refreshments such as coffee and tea. This affects the overall cost of the electricity used but does not effect the trends observed. The variable costs are directly related to the use of electricity when customer styles are being created. The relationship between fixed and variable costs has been shown in chapter 3 in figure 3.2.

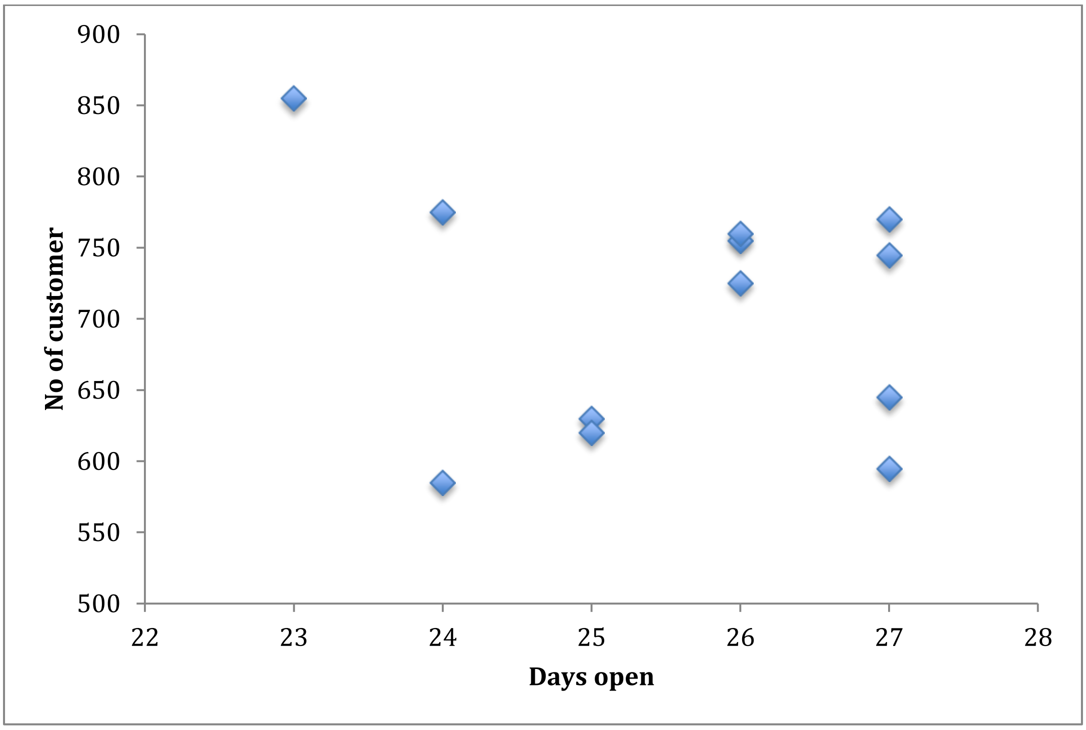


Figure 5.8. Relationship between number of days open and number of customers

One would expect the trend to be generally a linear increase for lower number of days open in the number of customers and then level off to saturation however at this level of business where is an established enterprise the number days open has little impact and the number of customers are related to the time of year and holiday period. The lowest number of days the salon is open is during December due to Christmas vacation, however in that period the number of customers is highest.

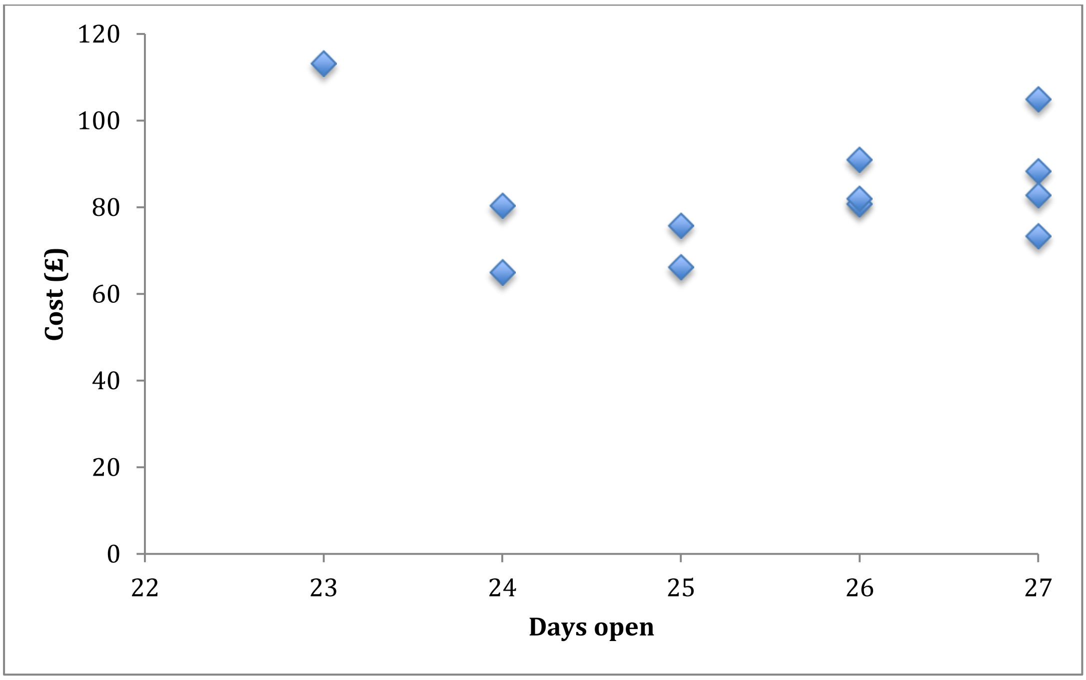


Figure 5.9. Relationship between cost of electricity and number of days open

The costs per month average at about £80 per calendar month but with unusually high cost for December where the salon was open for only 23 days but exhibited the highest level of costs. This may be attributed to the busiest period of the year Christmas where the most variety of hair styles were required hence this is not a surprising result.

5.2.2 Styles of haircut and tools employed

The salon offers a variety of haircut styles including:

i) **Restyle** involves wash, cut, blow dry and style

ii) **Wet cut** involves spraying hair with water spray and cutting using clippers and scissors

iii) **Scissor cut** involves the sole use of scissors

iv) **1 guard clipper** this uses a fixed number to give an even haircut all over

v) **2 guard clipper** uses two different sizes

These styles have different costs associated with them. However, there is a discount applied for pensioners and young children. The old aged pensioners are given a flat rate of £5.50 and young boys under the age of 12 years are charged £7.50.

The costs for each style is given in table 5.5 and shown in a bar chart 5.10.

Style	**Cost (£)**
Restyle	16
Wet cut	13
Scissor cut	13
1 clipper	7
2 clipper	9

Table 5.5. Style of haircuts offered by the salon

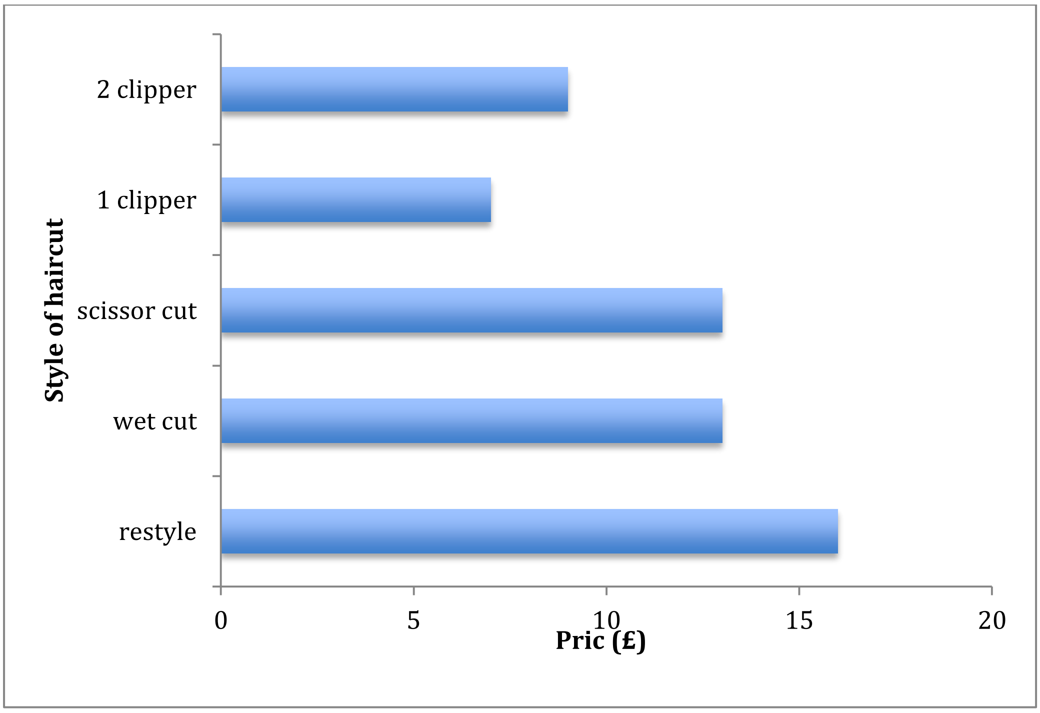


Figure 5.10. Bar chart showing the price and style of haircut

Customer	Time taken (min.)	Large Clipper time (min.)	Small Clipper Time (min.)	Hair Dryer Time (min.)	Shower Time (min.)	Cut Cost (£)
1	23	6.40	1.50	1.11		13
2	25		2.11	2.30	3.5	16
3	20		2.16	1.50		13
4	15	4.55	2.10	1.20		7
5	28	3.30	7.50	1.09		13
6	25	3.20	2.30	1.22		13
7	25		2.20	1.55	3.2	16
8	20	7.43	2.05	1.05		13
9	22	4.37	2.31	1.24		13
10	27	5.49	2.10	1.21	4.2	16
11	22	6.15	1.31	1.25		9
12	19	5.20	2.02	1.34		7
13	17		5.50	2.50		7
14	24	6.53	1.25	1.18		13
15	20	7.43	2.32	1.22		9
16	25		2.22	2.20	3.2	16
17	24	4.33	1.23	1.19		13
18	15	6.54	2.20	1.05		7
19	19	5.40	2.50	1.45		9

Table 5.6. Various tools used along with associated time and costs

The typical use of cutting tools and time used for customer 10 on, which all the tools were used, is given table 4.6 and pie chart 5.10.

Tool	Time (min)
Small clipper	2.1
Large clipper	5.49
Hair dryer	1.21
Shower	4.2
Total time	27

Table 5.7 Use of tools for a restyle of haircut

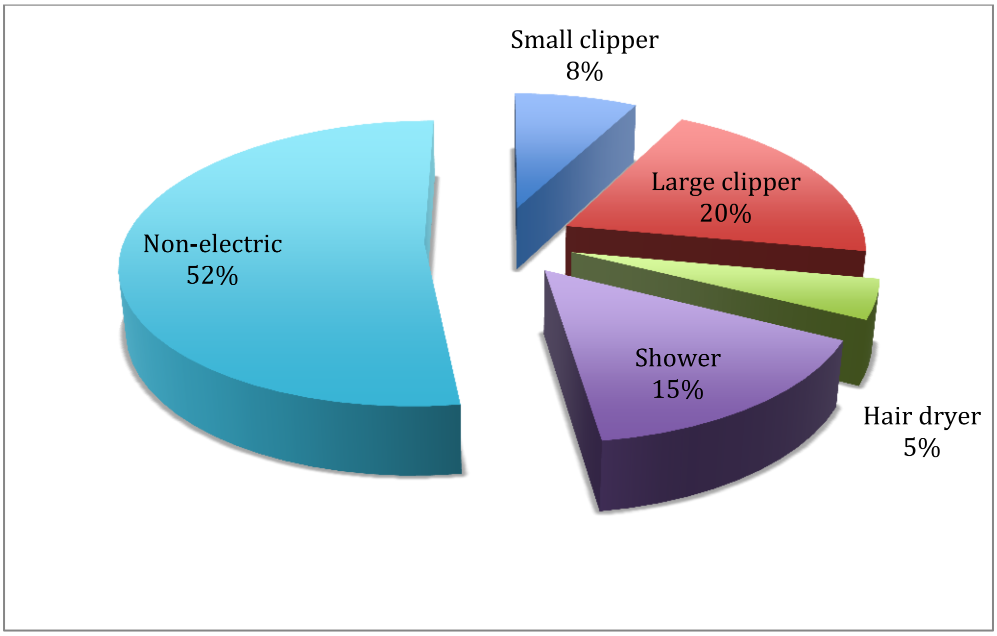


Figure 5.11. Use of various electric and non-electric cutting tools and time taken

Four types tools were used which were scissors, small clipper, large clipper, a hair dryer and a shower. Of these the small and large clipper and hair dryer required the use of electrical energy whilst the scissors used manual energy. The total time taken was 27 minutes whilst the electrical tools were used for 13 minutes. The rest of the time was allocated to scissor use, transition time and socialising.

Large clipper	Small clipper	Total
6.40	1.50	7.90
4.55	2.10	6.65
3.30	7.50	10.80
3.20	2.30	5.51
7.43	2,05	9.48
4.37	2,31	6.63
5.49	2.10	7.69
6.15	1.31	7.46
5.20	2.02	7.22
6.53	1.25	7.78
7.43	2.32	9.75
4.33	1.23	5.56
6.54	2.20	8.74
Mean = 5.46	Mean= 2.32	Mean = 7.78

Table 5.8 Use of large clipper with small clipper in terms of time

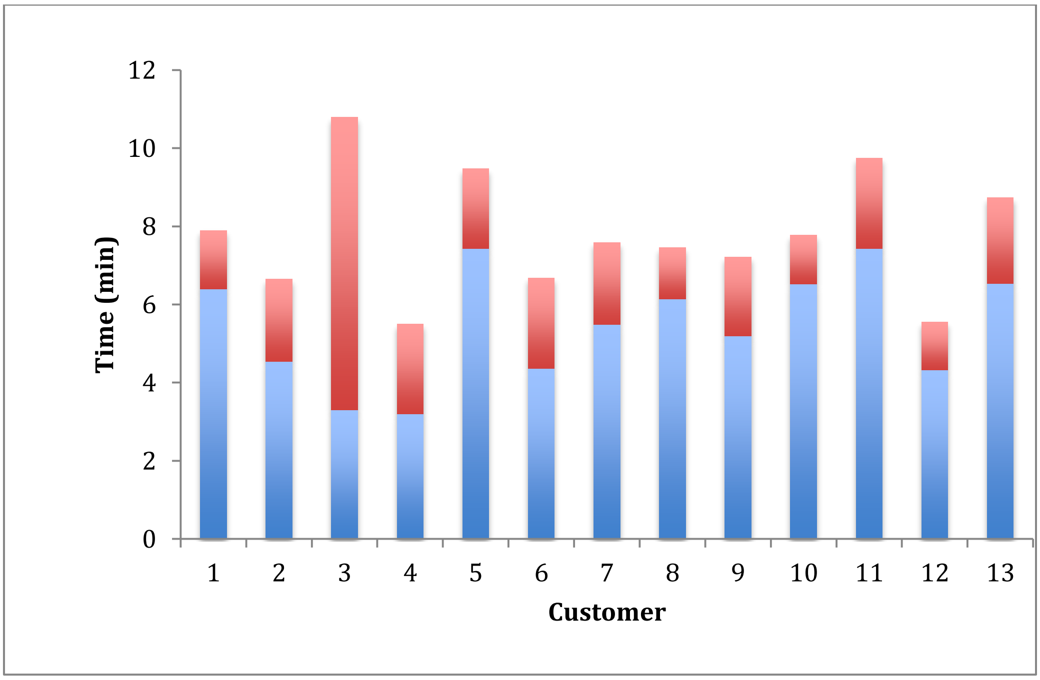


Figure 5.12. Use of the small clipper and large clipper per customer (red – small clipper and blue – large clipper)

The bar chart shown in figure 5.12 shows the relative use of large clipper compared to small clipper for 13 customers. The average time when clipper is used is calculated to be 7.78 minutes. A general observation from the bar chart is that large clippers are used more extensively than small clippers. This is as expected because large clippers do most of the work in getting the hair to the correct length around the majority of the head whilst small clippers are used for finishing and refining the hair cut around the edges of the hairline. The average time the large clippers are used 5.46 minutes and for small clippers it is 2.32 minutes.

5.2.3 Relationship income generated and time taken

As a business the efficient utilisation of time for each stylist is of significant importance. Table 5.9 shows the data for time taken and the income generated for customers.

Customer	Total time taken (min)	Revenue (£)
1	23	13
2	25	16
3	20	13
4	15	7
5	28	13
6	25	13
7	25	16
8	20	13
9	22	13
10	27	16
11	22	9
12	19	7
13	17	7
14	24	13
15	20	9
16	25	16
17	24	13
18	15	7
19	19	9
Total	**415**	**223**

Table 5.9. Income generated and time taken for each customer for a typical day

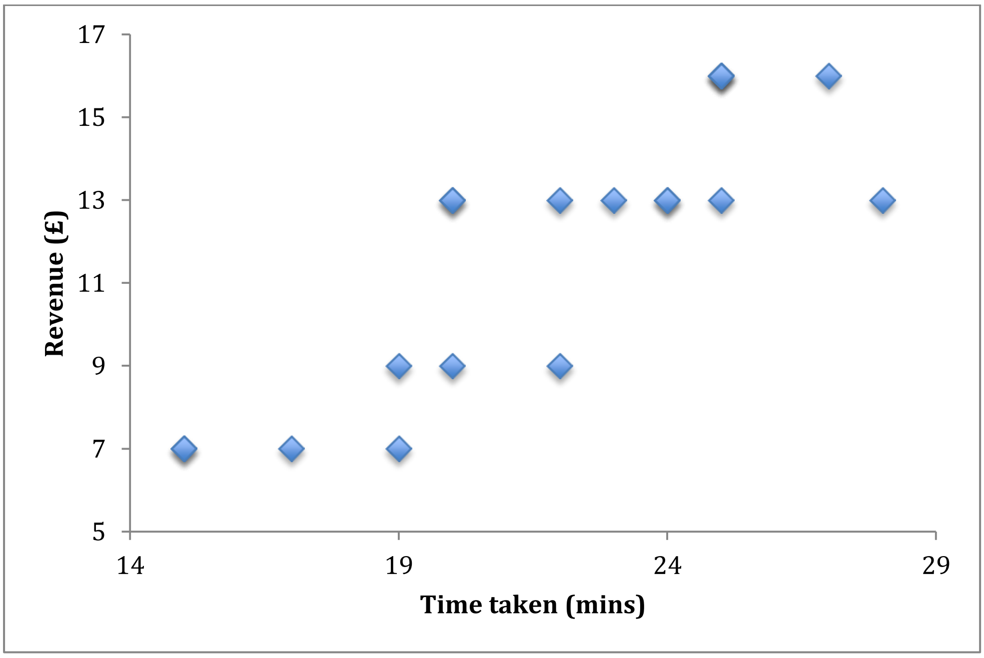


Figure 5.13 Relationship between revenue and time spent

There appears to be a linear relationship between the revenue generated and the time spent with a moderate correlation. In general it takes between about 15 to 30 minutes for a haircut and the revenue ranges from £7 to £16. The average time taken is calculated to be 22 minutes with average revenue of about £11.74. Therefore the revenue for a unit of time can be calculated £11.74 / 22 = 53 pence / min, which is an income rate of £32.02 per hour.

Style	Revenue (£)	Average time (min)
1 Clipper	7	16.50
2 Clipper	9	20.50
Wet cut	13	23.35
Scissor cut	13	23.35
Restyle	16	25.50

Table 5.10.Various styles, revenue and average time spent

The bar chart in figure 5.14 shows the relationship between style, revenue and time taken.

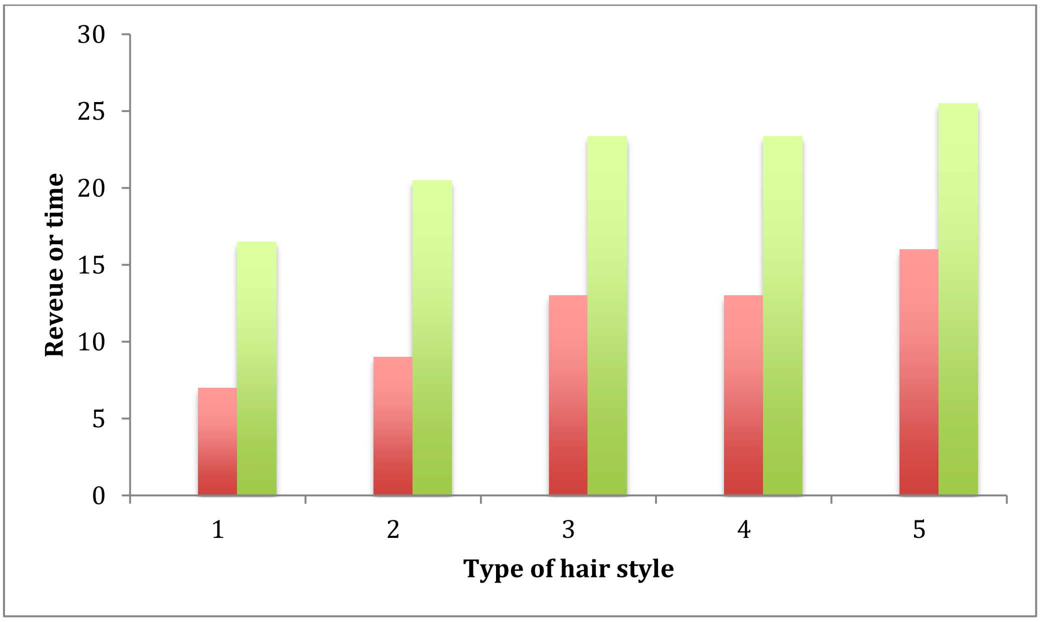


Figure 5.14 Style, price and time (green bars represent time in minutes in the y-axis and the red bars represent time taken in minutes on the y-axis. On the x-axis 1 is one clipper cut, 2 represents two clipper cut, 3 is wet cut and 4 represents a scissor cut and 5 is the complete restyle. Each style has a different price)

The bar chart shows that moving from the left to the right, the revenue generated and time taken generally increase. It is also known that going from style 1 to style 5 the hairstyles become increasing more sophisticated taking longer time to finish.

The hair dryer is routinely used to finish off a hair on each customer; however it also has the highest electricity consumption. Table 5.17 shows the use of hair dryer and time spent using it.

Customers	**Dryer time (min)**
1	1.11
2	2.30
3	1.50
4	1.20
5	1.09
6	1.22
7	1.55
8	1.05
9	1.24
10	1.21
11	1.25
12	1.34
13	2.50
14	1.18
15	1.22
16	2.20
17	1.19
18	1.05
19	1.45
Total	**26.85**

Table 5.11 Customer and use of hair dryer

The average time the hair dryer was used for a customer is calculated to be 1.41 minutes. This is a relatively short procedure performed just before finishing touches to the haircut. It appears that each customer requires different time for a haircut due to different style desired. A haircut takes between 15 to 28 minutes. The use of shower is only been with some particular hairstyle, and the lowest time shower been used for hair cut 3.2 minutes and the highest time shower been used was 4.2 minutes. The average time is calculated to be 3.5 minutes.

Customer	Shower time (min)
2	3.5
7	3.2
13	4.2
16	3.2
Total	**14.1**

Table 5.12. Customers requiring use of shower and associated times

5.3 Power ratings, time used, energy used and cost

The power used by the tools used in cutting hair is given table 5.20 for a day that data was collected. This was used to determine localised electricity cost for each tool used in the Groom Gents hair salon.

Equipment	Rating (kW)	Time used (hr)	Energy used (kW)	Cost (£)
Large clipper	0.01	1.27	0.0127	0.00254
Small clipper	0.005	0.78	0.0039	0.00078
Hair dryer	2	0.45	0.9	0.18
Shower	7.5	0.24	1.8	0.36
Other uses				
Lights	0.06 x 20	10	12	2.40
Heating	2	6	12	2.40
Radio	0.2	10	2	0.40
Computer	0.1	10	1	0.20
Kettle	2	0.5	1	0.20
Total	**15.02**	**39.24**	**30.72**	**6.14**

Table 5.13. Daily use of electrical devices, power, time, energy and cost

Even though the music and computer are on all day without interruption these two items have the lowest cost. The kettle is only on to boil the water for tea and coffee and therefore even though the kettle consumes a significant amount of electricity the low cost can be attributed its very low utilisation during the working day. The highest cost is the electricity consumption due to the heating and lighting elements. The energy used by each electrical tool was calculated using the formula.

Energy = Power x Time Eq. 5.3

The cost of electricity has been calculated using the formula

Cost = Energy Used x Price Eq. 5.4

Hence the daily cost has been calculated to £6.14 and the monthly and annual 2012 cost.

Month	Days open	Monthly energy used (kW)	Calculated Monthly energy (£)	Actual Monthly Electricity bill (£)
Jan	25	768	153.50	79.44
Feb	25	768	153.50	90.96
Mar	27	829	165.78	106.08
Apr	24	737	147.36	78.00
May	27	829	165.78	88.08
Jun	26	799	159.64	96.96
Jul	26	799	159.64	109.20
Aug	26	799	159.64	98.40
Sep	24	737	147.36	96.48
Oct	27	829	165.78	99.36
Nov	27	829	165.78	126.00
Dec	23	707	141.22	135.88
Total	**307**	**9430**	**1884.98**	**1205.28**

Table 5.14. Calculated monthly energy utilization and actual energy costs

The salon opened 307 days in the year 2012 using 9,430 kW of electrical energy, hence the monthly theoretical cost of electricity was £1884.98 and the actual electric bill was £1205.28. The difference between the theoretical and actual value as 1884.98 – 1205.28= £ 679.70 annually. Hence the daily difference between the theoretical and the actual electrical energy used was calculated by dividing by 307 days gave £2.21. As a percentage of the daily rate the amount can be calculated as

$$\%\ \boldsymbol{difference} = \frac{\boldsymbol{difference}}{\boldsymbol{total}} \boldsymbol{x100} \qquad \text{Eq. 5.5}$$

which gives

$$\% \, \boldsymbol{difference} = \frac{\mathbf{2.21}}{\mathbf{6.14}} \times \mathbf{100} = \mathbf{35.99}$$

The reasons for the discrepancy between actual and calculated values will be discussed in the next section.

5.4. Error analysis

As mentioned in the previous section the 35.99% variation can be attributed to several sources of error and these will be summarised. The calculation began as a soon the stylist picks up the tool and stopped when the tool is placed on the rack. It was assumed the tool is used continuously during that period. However, practical business considerations dictate that the operation maybe interrupted to answer customer questions, make a judgment on the haircut and the transition to the next stage. For example, during the shower presider the timer switch on when customer set on the chair, and only switch off when the customer stand up from the char. However, in between the customer hair is dried with towel or a conversation may take place or any other adjustments which introduce an error and cause give you allow actual value of electricity use compare to the calculation value. In addition, every wash requires the use of a conditioner and the shower runs continuously wasting electricity while the stylist waits for the effect of the conditioner to complete and then rinses it off. The error of 35.99% can be analysed in terms of fixed costs and variable costs. The fixed costs were the same every day of the year since the heating and lighting components form a major proportion of these costs. The large errors are due to the variations in hair styles, instruments used, time taken, the speed and efficiency of the stylist. These human variables are difficult to standardize. In addition, each customer is different and has different demands and expectations. As business customer satisfaction is of immense importance but introduces additional variable.

5.5 Solar energy as an alternative to fossil fuels

In recent years significant developments have taken place in solar energy from solar cells (Kabalci, 2013) . Silicon based solar panels have been promoted for domestic use with the government offering financial incentives to home owners for installing solar cells on their roof. Major barriers to adaption of this technology include the unattractive appearance, installation costs and the low efficiency of solar cells. However, the efficiency of solar cells has been increasing annually for the past couple of decades as new materials and architectures have been developed (Sudhakara Reddy, 2013).

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 (Al-Salaymeh et al., 2010). 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 rood, sunlight intensity 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. However, the efficiencies of commercial solar are expected to rise because research has already produce efficiencies that are much higher than commercially available ones. In the past few years the adaption of solar panels widely has increased significantly due for several reasons:

i) The development of China as a world manufacturing base has made the cost of solar cells much more affordable than previously.

ii) The efficiency improvements has also made it feasible to consider the replacement of non-renewable sources

iii) Technological developments have also made solar panels more reliable and readily installed on roofs of buildings

iv) The government in the UK has introduced more investment and incentives for homes to install solar panels on roofs.

In general the costs of electricity per W has decreased significantly since the 1990's and dipped below £1.00 in the year 2012 and further decreases are expected.

5.5.1 Solar cells adaption and reduction in CO_2

Efficiency improvements, cost reduction and better reliability have caused a rapid rise in the adoption of solar energy to replace non-renewable fossil fuel source (Allani et al., 1997). An exponential rise in the adoption of the technology in the USA has occurred recently. This will help prevent CO_2 from getting into the atmosphere and improve the environment. For example, vehicles generate the largest amount of CO_2. Consider diesel and petrol as sources of CO_2 (Santoyo-Castelazo et al., 2014)

Consider in the USA how much CO_2 can be prevented from entering the atmosphere, it has been calculated that in the USA 1KWh electricity generates an equivalent of 0.58kg of CO_2 compared to UK figure of 0.43 kg (Hammond and Spargo, 2014). Hence, the amount of CO_2 that can be prevented from entering the atmosphere can be calculated. In 2012 on average approximately 100 GW capacities was installed and theoretically replace the fossil fuel sources and in about 3 years subsequently this number is predicted to double. Therefore, the amount of CO_2 for 2012 can be calculated (Muneer et al., 2003).

1GWh = 0.58 x 1,000,000 kg of CO_2 = 580,000 kg of CO_2

In 2012 in the USA the solar cell installed capacity was an average of 100 GW giving a value of CO_2 to be 58,000,000 kg which was predicted to enter the atmosphere due in USA. The cumulative capacity is set to double by 2015 and therefore the amount of CO_2 that can be prevented from entering the atmosphere causing environmental damage is calculated to be 116,000,000 kg of CO_2. The developed countries including USA, UK, Germany, Hong Kong, Taiwan, Mexico and Switzerland account for 3.67 kg of CO_2 per kW. It is not surprising to learn that Hong Kong has the highest production of

CO_2 since it is a densely populated and vibrant city.

5.6 CO_2 from Groom Gents Hairdressing

It is instructive to investigate how much CO_2 is generated by a small hairdressing salon such as Groom Gents Hairdressing salon in the UK

Units consumed (kWh)	**UK CO_2 (kg)**
331	142.33
379	162.97
442	190.06
325	139.75
367	157.81
404	173.72
455	195.65
410	176.3
402	172.86
414	178.02
525	225.75
568	244.24
5022	**2159.46**

Table 5.15. Units of electricity consumed and the carbon dioxide generated

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. By replacing non-renewable source with solar panels we can prevent CO_2 from being released into the atmosphere to cause global warming and other environmental disasters. Since there are millions of businesses in the world this will have a significant long-term impact.

5.7 UK and Iraq comparison

Since solar cells rely on light for their mode operation it is useful to compare UK with Iraq. Iraq has an abundant supply of sunshine and long daylight.

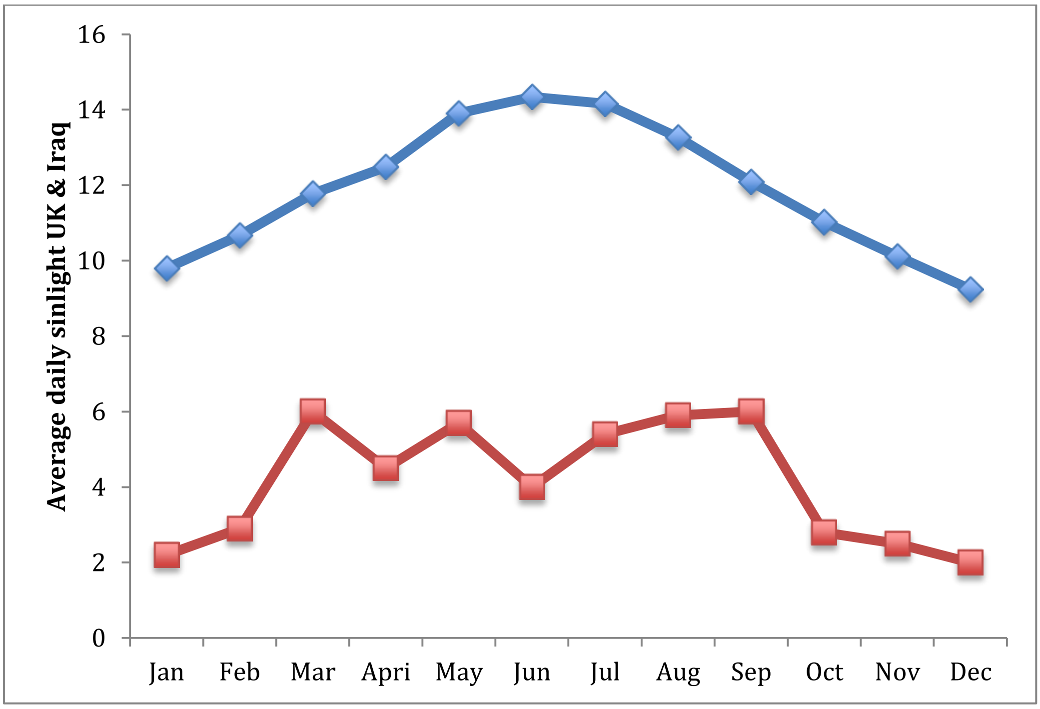


Figure 5.15. Average daily sunshine in Iraq and UK in 2012

Figure 5.15 shows the seasonal variations in the average number of daylight hours with the begin and end of the year having lower number of daylight hours corresponding with the winter months in the UK. The use of solar cells in the UK is more suitable in the summer months generating more electricity compared to the winter months. In Northern Iraq the peak number of daylight hours are in the middle of the year and lower at the beginning and end of the year. The trend is more stable and predictable in Northern Iraq and much less predictable in the UK. Obviously photovoltaic technology operating by using incident light irradiation work best in the summer months when there is more light compared to winter months.

In 2012 the figures for daylight are shown in Figures 5.15 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. When this compared to Northern Iraq the figure are 10hours and 14hours respectively per day. Hence, it not surprising that the weather conditions in Northern Iraq are more conducive to solar cell technology than the UK.

The expected electricity generated can be calculated as follows:

$$\boldsymbol{Electricity = A \times 1000 \times E \times t} \qquad \text{Eq. 5.6}$$

A is the area of solar panels, E is the efficiency and t is the hours of sunlight give the electricity generated in Wh per day.

For example: 2 square meter panel x 1000 = 2000 x 0.20 (20% efficiency panel) = 400. Hence, 400 x 5 hours of sun hours = 2000 Watt hours per day.

Consider the Grooms Gents Hairdressing Salon and using figure 5.14 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.

Using the equation 5.6 the amount of electricity generated in a typical day UK is

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

The efficiency was assumed to be about 20% with day light hours to be 4 typical an average in the UK in 2012 and the amount of electricity generated per day would be 4.8

kWh/day. Compared with Northern Iraq the calculation involves longer hours of daily sunlight and the intensity of sun is also much higher hence repeating the calculation gives

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

In Iraq the amount of electricity generated for an equivalent business unit using the same solar cells 14.4 kWh/day electricity can be generated compared to the UK due to better weather conditions and therefore use of solar energy is much more attractive. This is 3 times more electricity can be generated in Northern Iraq compared to the UK making more attractive as a environmentally friendly technology for energy production. As mentioned earlier in the literature review the trend in solar cell technology is towards increased efficiency and also toward more versatile organic solar cells, which can be applied to windows readily in the form of a transparent thin film.

Applying these solar cells to windows of Gents Groom Hairdressing Salon and assuming that the efficiency will rise to 20% from an existing value of about 5% the proposition for solar cells as a viable alternative to fossil fuels is becoming increasingly more attractive. Application of flexible solar cells to windows can provide additional electricity.

The windows on the Gents Groom Hair Salon measure

2.1 x 3.8 = 7.98 m^2, which is approximately 8 m^2

Therefore 2 windows give an area of 16 m^2 and the amount of electricity that could be generated can be calculated using equation 5.6.

Electricity (UK) = 16 x 1000 x 0.2 x 4 = 12,800 Whr/day = 12.8 kWh/day

Electricity (Iraq) = 16 x 1000 x 0.2 x 12 = 38,400 Whr/day = 38.4 kWh/day.

Hence in Iraq 3 times more electricity can be generated per day using flexible organic

solar cells. Based on UK figures (0.43 kg/kWh) it can be calculated amount of CO_2 reduction if a switch was made from non-renewable fossil fuels to flexible organic solar cells and for Northern Iraq used Mexico (0.52 kg/kWh) was used.

	UK	**Northern Iraq**
12.8 kWhr x 365	4,672 kWh/year	
38.4 kWhr x 365		14,016 kWh/year
CO_2	2,009 kg	7.288 kg

Figure 5.16 Comparison of UK and Northern Iraq of amount of CO_2 reduction with using solar cell technologies instead of fossil fuels

Clearly from the calculations above the replacement of fossil fuels with solar cells will reduce the carbon emission into the atmosphere and reduce damage to the environment.

The benefits in Iraq would be much greater due to more sunlight being available and a about 5 times the reduction can be achieved in Northern Iraq compared to UK and this is also applicable to other countries in the Middle East.

5.8. Conclusions

Groom Gents Hair Salon was analysed in terms of business cost and operation and energy utilization from conventional fossil fuels. The usage of each tool was analysed and related to energy consumed during operation. This was related to data of the overall energy input. The daily energy utilized was converted to annual usage and a relationship between energy utilization and carbon emissions was established. The feasibility of replacing the energy demand with solar cells was explored and it was shown how if

solar energy was implemented then significant carbon emissions would be prevented entry into the atmosphere thus reducing environmental damage. For this business unit predictions were made regarding the future use of flexible solar cells and how these would further reduce carbon emissions.

CHAPTER SIX

CASE STUDIES OF SMALL AND MEDIUM SIZED ENTERPRISES

CASE STUDY ONE

STUDY AND ANALYSIS OF BLUE APPLE PRINTING

6.1 Introduction

In this chapter Blue Apple Printing has been studied and data analysed using an approach similar to that used for Gents Groom Hairdressing. Data has been collected on the power rating, time utilised for each component using electrical power. This has been followed by analysis using EXEL and MATLAB. The feasibility of replacing the actual electricity used with solar energy is explored using existing silicon based solar cells and flexible organic solar cells (Essalaimeh et al., 2013). A comparison scenario is considered between printing shops in the UK and N Iraq.

6.2 Methodology and approach

A list of the equipment using electricity was made. The power ratings were noted. Over a period of two months the time that each machine used was measured (Zhang et al., 2013). The data obtained was analysed using EXEL and MATLAB in order to determine trends and explore various features. Using known and projected solar cell efficiencies the possibilities of replacing all or proportion of fossil fuel sources was investigated. A comparison between UK and Iraq made. The relationship between electricity usage and CO_2 was developed and calculations regarding the amount of CO_2 that can be prevented from entering into the atmosphere completed.

6.3 Results and discussion

6.3.1 Analysis of electrical energy used in Blue Apple Printing in 2012

Table 6.1 shows the monthly units used, cost of electricity incurred and the number of days the business is open is open during. The sum, mean, minimum and maximum have been calculated.

Month	Units Used (kWh)	Cost (£)	Days Open
Jan	355	69.14	26
Feb	367	71.42	25
Mar	532	97.59	27
Apr	574	109.78	25
May	461	89.26	27
Jun	426	83.11	26
Jul	427	83.29	26
Aug	404	79.21	27
Sep	460	88.71	25
Oct	543	104.32	27
Nov	416	80.61	26
Dec	372	73.15	20
Sum	**5337**	**1029.59**	**307**
Mean	**444.75**	**85.80**	**25.58**
Min	**355**	**69.14**	**20**
Max	**574**	**109.78**	**27**

Table 6.1 Data obtained for 2012 from Blue Apple Printing

Figure 6.1 shows the number of units of electricity consumed over the months in 2012. To smooth out variations a two-point moving average was used to obtain a trend line. It appears from the data that the electricity utilisation reaches a peak in Easter months, dips and peaks again in the September. This may be due to business getting ready for marketing campaigns for the summer and for Christmas.

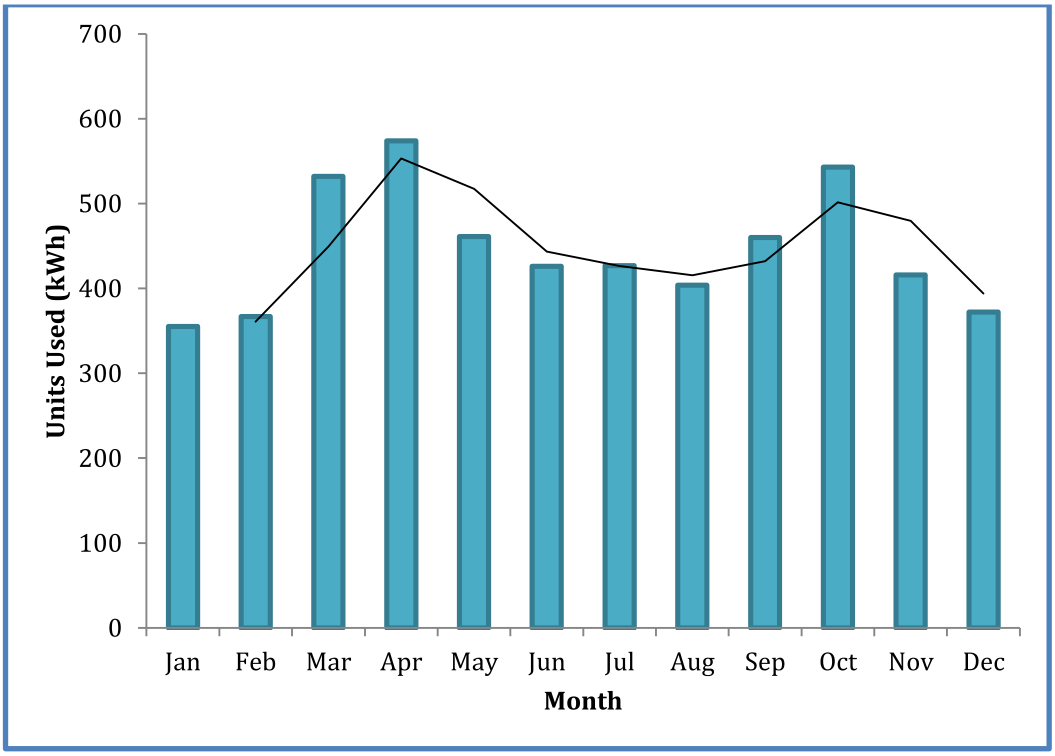


Figure 6.1. Units of electricity consumed during months in 2012

The number of days the business was open was plotted for each month in figure 6.2 and there is a dip in the line in December due to Christmas closure when the business was only open for 20 days. This can explain the small number of units of electricity used in December. During the rest of the year there is only 2 days variation in opening of the business.

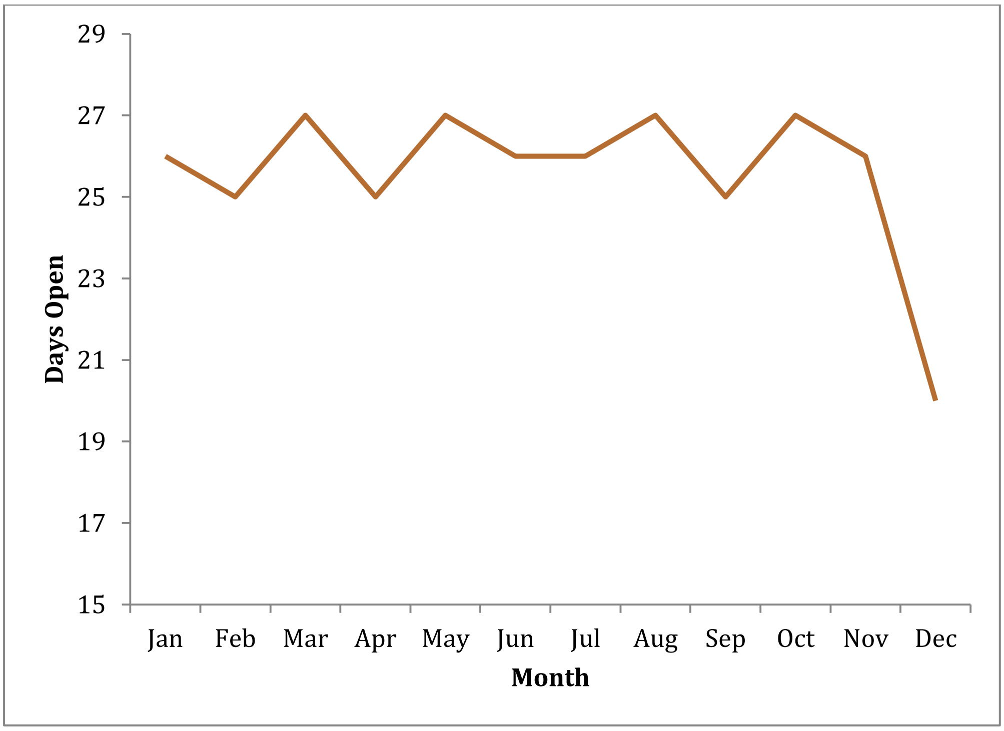


Figure 6.2. Opening days in months of 2012

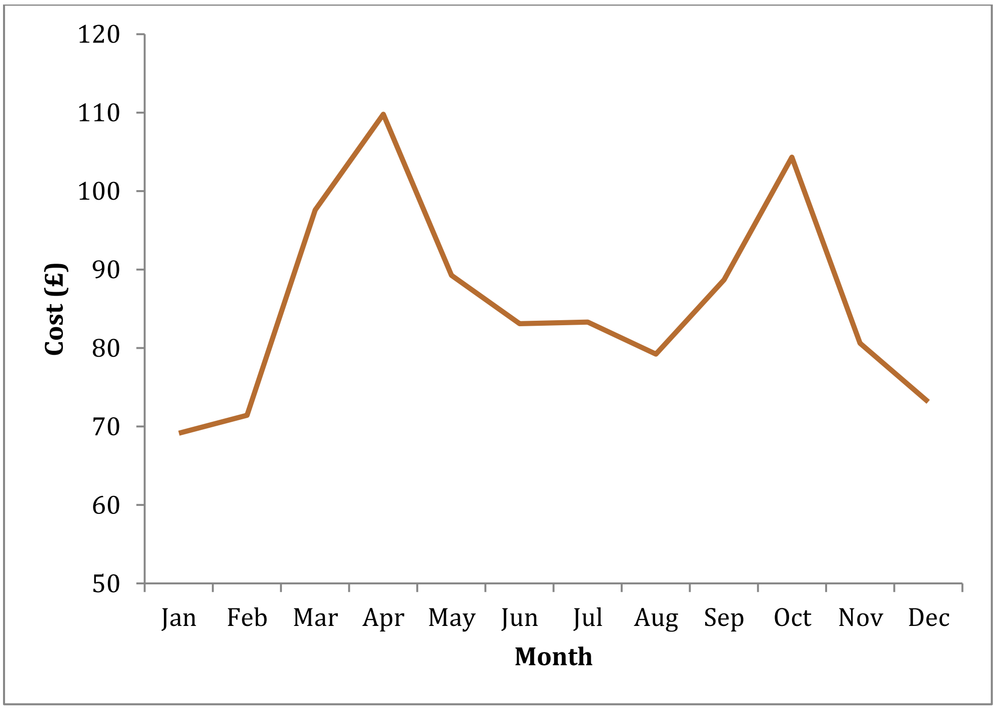


Figure 6.3. Monthly costs of electricity in 20102

The average cost of electricity is about £82. A peak occurs in October perhaps due to businesses preparing for Christmas. When considering costs against the units of electricity consumed one would expect a clear linear trend and this is shown in Figure 6.4. This is indeed observed.

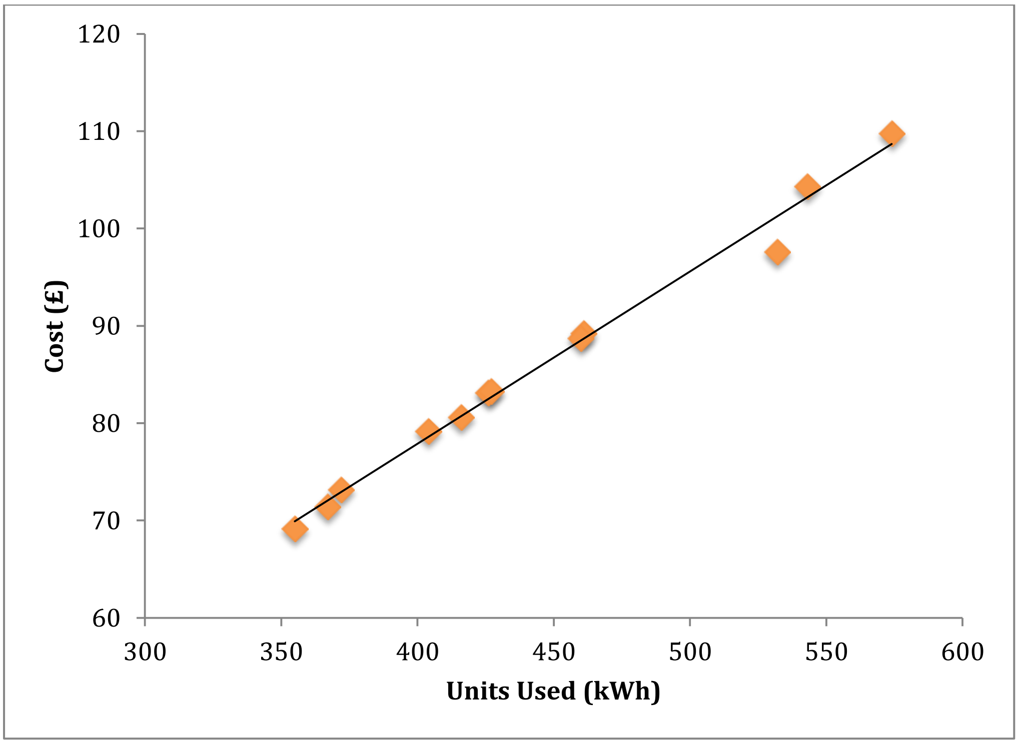


Figure 6.4. Relationship between costs of electricity and units used

As explained in the previous chapter normalization was used to compares trends in dataset at very different range of values. The relationships between costs, units used and number of days open can be examined closely by normalising the data.

The normalised data for the number of days open, units of electricity used and the monthly cost are plotted below in figure 6.5.

Month	Units Used (kWh)	Cost (£)	Days Open	Normalised Units	Normalised Cost	Normalised days
Jan	355	69.14	26	0.7978	0.8461	1.0164
Feb	367	71.42	25	0.8247	0.8739	0.9773
Mar	532	97.59	27	1.1955	1.1942	1.0555
Apr	574	109.78	25	1.2899	1.3434	0.9773
May	461	89.26	27	1.0359	1.0923	1.0555
Jun	426	83.11	26	0.9573	1.0171	1.0164
Jul	427	83.29	26	0.9596	1.0192	1.0164
Aug	404	79.21	27	0.9079	0.9693	1.0555
Sep	460	88.71	25	1.0337	1.0855	0.9773
Oct	543	104.32	27	1.2202	1.2766	1.0555
Nov	416	80.61	26	0.9348	0.9864	1.0164
Dec	372	73.15	20	0.8359	0.8951	0.7819

Table 6.2. Normalised data against the mean of days open, units used and cost

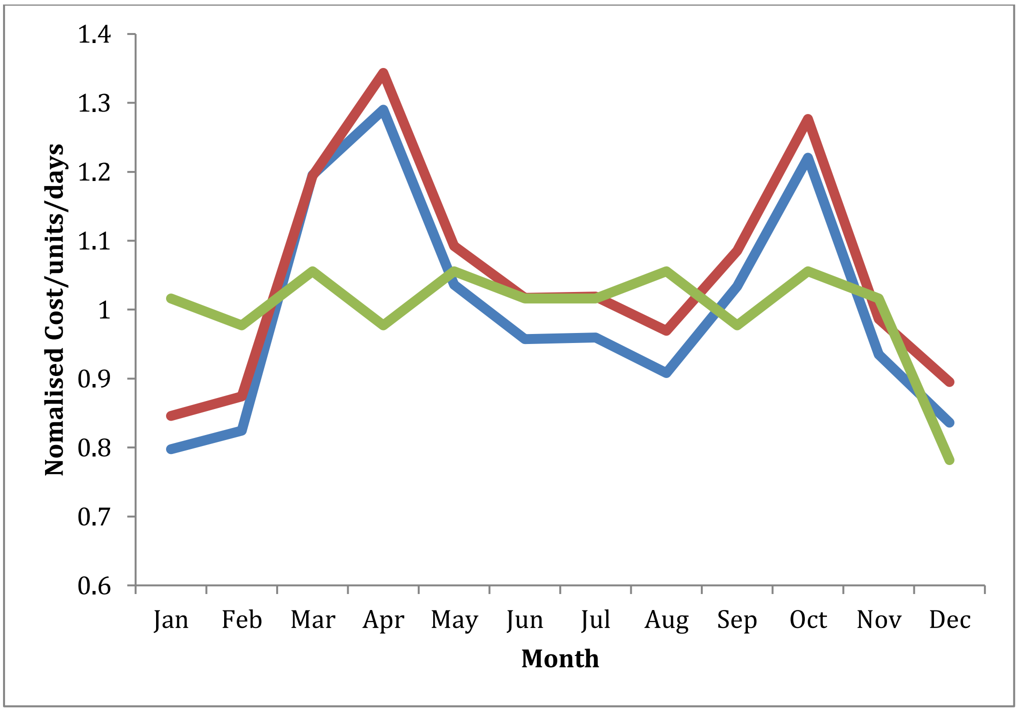


Figure 6.5. Normalised data plotted against month in 2012. (Green – days open; Red – units used; and blue – cost of electricity).

It is evident from the figure that the number of days open is almost linear with the variation of 2 days expect during Christmas break where the printing shop was closed for 10 days as shown by the sharp dip in the line. The number of units used and cost of the electricity show that the lines are very similar trend indicating a close relationship between the units used and cost of electricity incurred as expected.

6.3.2 Analysis of the machines usage

In the following sections the utilisation of machine used for printing has been investigated and analysed over a period of two separate months. Table 6.3 shows the utilisation times for each machine used.

Days	Large Format	Copier 1	Copier 2	Document Centre	Guillotine	Heat Press	Laminator
1	90	3	0	90	30	0	150
2	70	30	5	0	0	0	0
3	30	31	0	0	0	60	0
4	0	35	0	60	0	0	0
5	30	120	0	0	0	30	0
6	0	25	0	60	40	55	0
7	30	75	0	0	15	30	0
8	0	41	0	30	15	0	20
9	20	93	0	60	30	0	5
10	17	0	0	0	0	12	0
11	0	5	0	30	30	40	13
12	30	10	0	30	25	50	20
13	9	125	0	90	45	0	0
14	0	45	0	0	15	10	5
15	90	10	0	0	10	15	25
16	15	30	0	5	25	15	30
17	40	25	20	10	25	55	40
18	45	45	55	80	45	55	35
19	15	90	40	55	15	35	40
20	30	25	20	0	15	15	10
21	10	3	15	45	10	10	5
22	55	90	45	60	80	55	45
23	95	195	45	75	50	85	20
Sum	**721**	**1151**	**245**	**780**	**520**	**627**	**463**
Mean	**31.35**	**50.04**	**10.65**	**33.91**	**22.61**	**27.26**	**20.13**
Min	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Max	**95**	**195**	**55**	**90**	**80**	**85**	**150**

Table 6.3. Usage times in minutes of machines in December used in Blue Apple Printing

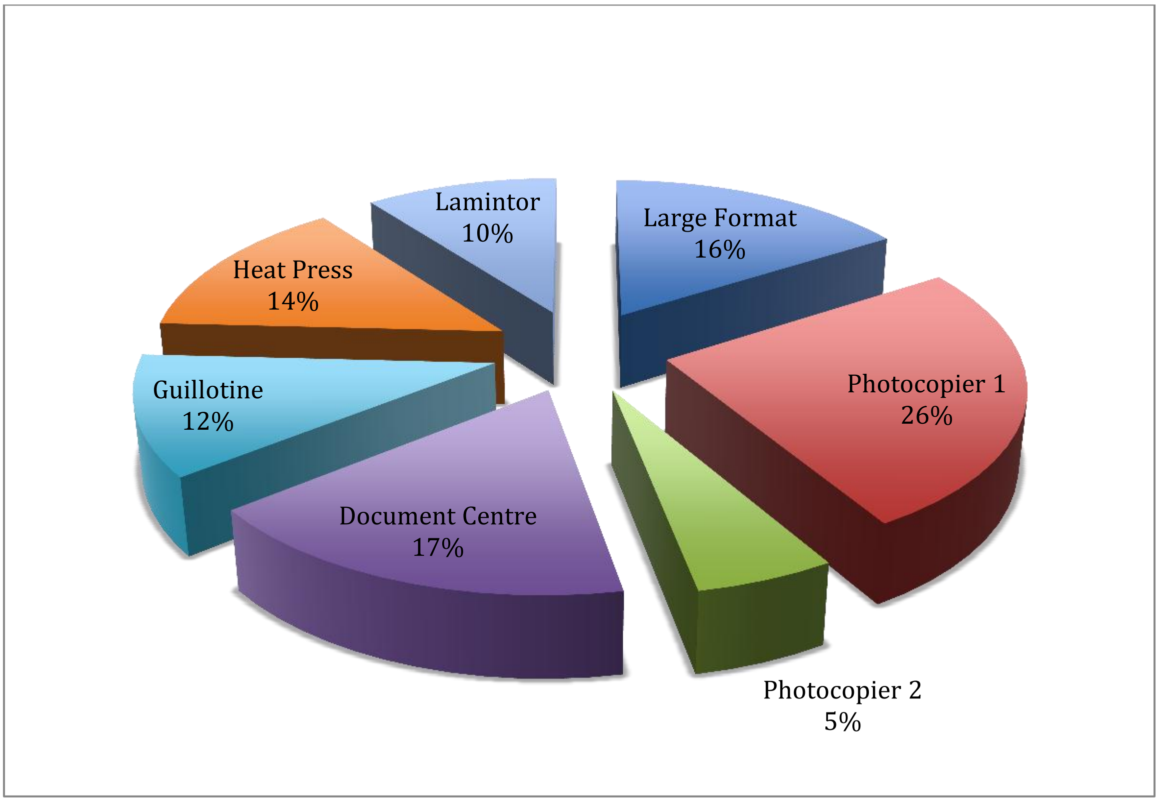


Figure 6.6. Overall usage time of machines used in Blue Apple Printing in December 2012

The analysis of each machine utilised over December is shown in figure 6.6. The busiest machines used were Photocopier 1, Document Centre and large format printer with utilisation percentages of 26%, 17% and 16% respectively.

The business was also investigated in November 2013 and the data is given in table 6.4.

Days	Large Format	Copier 1	Copier 2	Document Centre	Guillotine	Heat Press	Laminator
1	15	26	0	25	5	5	10
2	20	40	45	22	35	15	0
3	57	34	10	26	30	26	0
4	30	51	40	23	22	35	10
5	45	40	22	35	34	18	10
6	47	29	28	46	37	30	10
7	45	47	45	27	35	5	45
8	37	49	14	37	35	6	40
9	38	51	27	43	15	56	28
10	43	61	12	21	37	40	15
11	44	53	12	27	36	50	45
12	37	40	30	37	67	25	35
13	37	25	22	33	30	21	20
14	43	60	38	43	12	35	28
15	25	45	12	47	49	18	17
16	33	36	35	46	47	30	10
17	55	47	27	60	40	15	67
18	37	49	29	37	35	21	61
19	35	35	27	66	15	59	30
20	29	52	12	21	37	52	20
21	31	64	29	32	35	31	12
Sum	**783**	**934**	**516**	**754**	**688**	**593**	**513**
Mean	**37.29**	**44.48**	**24.57**	**35.90**	**32.76**	**28.23**	**24.43**
Min	**15**	**25**	**0**	**21**	**5**	**5**	**0**
Max	**57**	**64**	**45**	**66**	**67**	**59**	**67**

Table 6.4. Utilisation time for machines used in Blue Apple Printing in November 2013

The mean utilisation times have been used to determine the percentage utilisation in the business (figure 6.7).

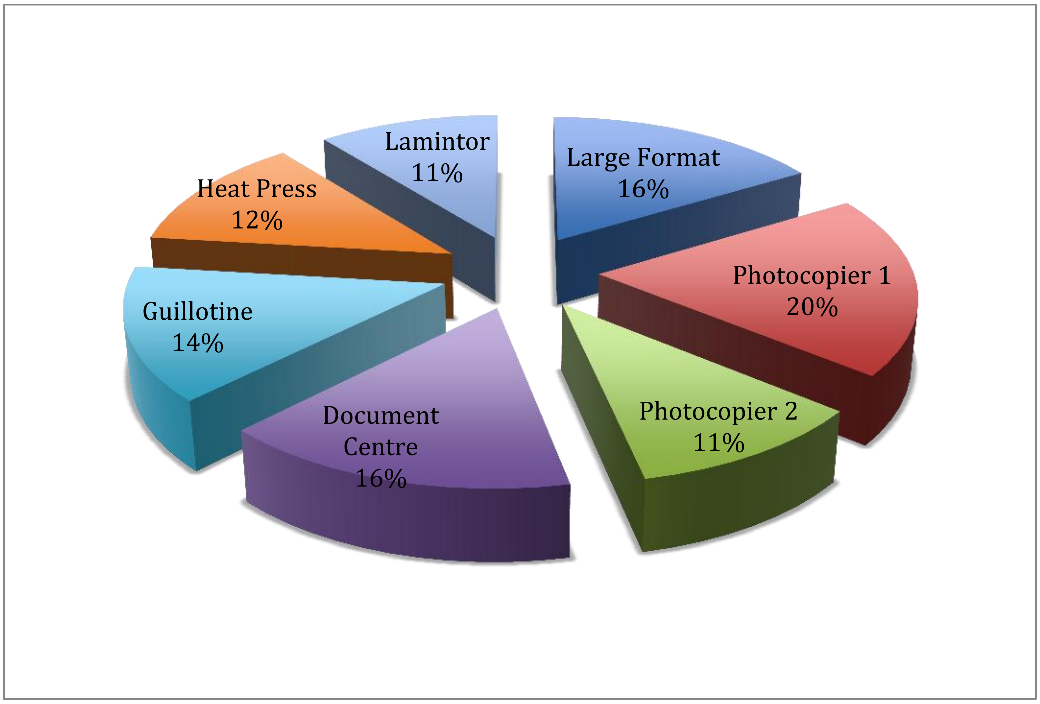


Figure 6.7. Utilisation percentage of each machine in November 2013

In November 2013 the utilisation times for the most frequently used machines were in Photocopier 1, Document Centre and large format printer with 20%, 16% and 16% respectively. The daily uses of each of the machines were investigated.

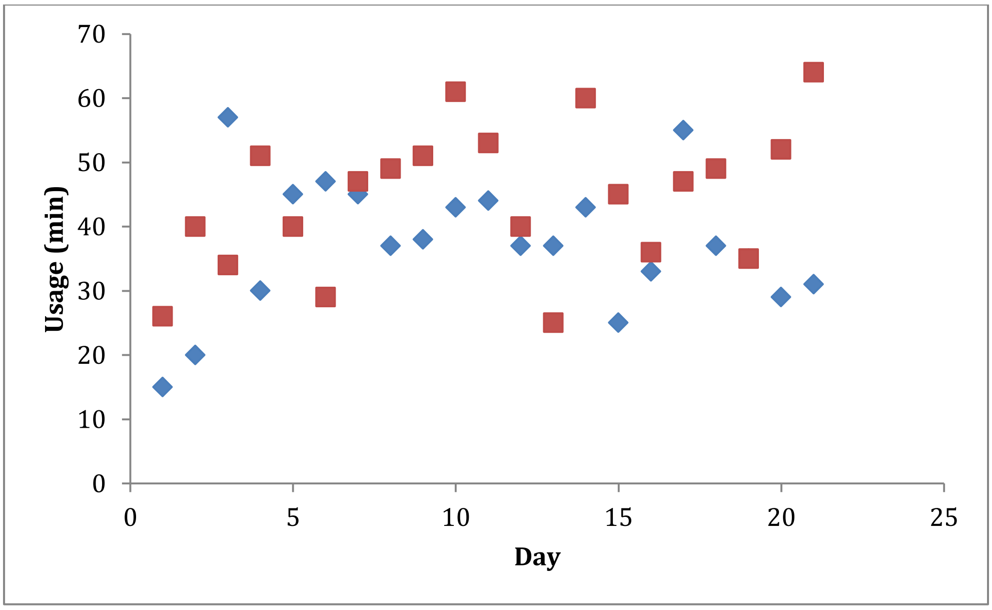


Figure 6.8. Daily use of large format printer and photocopier 1 in November 2013

Figure 6.8 shows no noticeable relationship between time utilised and day of the month. There is no trend in utilisation of wither of the two machines. Their specific use would depend on the order to be processed on the day and customers visiting the print shop.

6.3.3 Analysis of electrical energy used

The energy analysis was carried out for the machines used in printing during the month of November 2013.

Machine	Monthly Time (min)	Power rating (W)	P x t (Wmin)	P x t (kWh)
Large format printer	783	1080	845640	14.09
Photocopier 1	934	1080	1008720	16.81
Photocopier 2	516	1080	557280	9.29
Document centre	754	1425	1074450	17.91
Guillotine	688	1100	756800	12.61
Heat Press	593	1200	711600	11.86
Laminator	513	600	307800	5.13
Total	**4781**	**7565**	**5262290**	**87.70**

Table 6.5. Machines used during November 2013 with power rating, time used and the calculated electrical power used.

As an example a large format printer was in use for 783 hours and has a power rating of 1080 W. Hence 783x1080 = 845,640 and when converted to kWh gives 845640/(1000x60) = 14.09 kWh.

The overall power used by each machine has been calculated and plotted in figure 6.9. The highest use of electricity was by large format printer, documents centre and photocopier 1 and this coincides with these three machines used most frequently during business operations. The laminator had the lowest use of electricity and it was used less frequently than the rest of the machines.

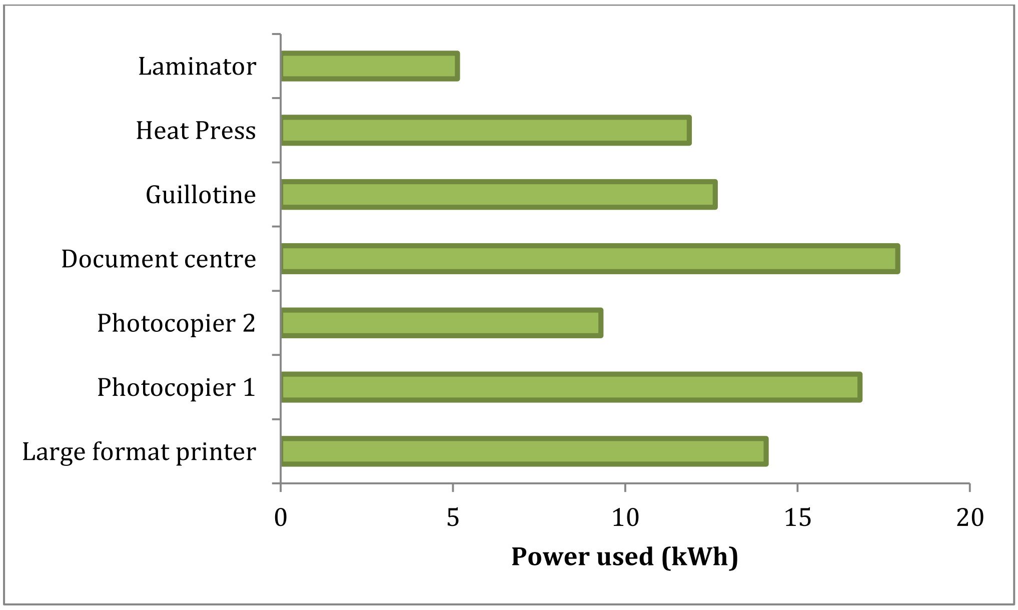


Figure 6.9. Power used by each of the machine in Blue Apple Printing

These machines also use electricity even when they are not used during sleep mode. Hence, more electrical power is actually used than calculated. The inactive modes for the machines and the electricity used are given in table 6.6. During the inactive modes the equipment uses far more electricity than the active mode but is necessary for the operation of the business. Some of the machines were in sleep mode.

Machine	**Power (Inactive mode) (kW)**	**Time (hours)**	**Electricity used (kWh)**
Large format printer	0.03	202.89	6.0867
Photocopier 1	0	200.44	0
Photocopier 2	0	207.00	0
Document Centre	0.065	203.44	13.2236
Guillotine	0	204.55	0
Heat Press	0.45	206.12	92.754
Laminator	0	207.45	0
Total	**0.545**	**1431.89**	**780.38**

Table 6.6. Electrical energy used in November during inactive mode

6.3.4 Carbon dioxide emission by electrical equipment used

The amount of CO_2 generated in kg by each machine used in the printing business can be calculated using the following equation:

Machine	**Inactive Electricity Used (kWh)**	**Active Electricity used (kWh)**	**Total Electricity used (kWh)**
Large format printer	6.09	14.09	20.18
Photocopier 1	0	16.81	16.81
Photocopier 2	0	9.29	9.29
Document Centre	13.22	17.91	31.13
Guillotine	0	12.61	12.61
Heat Press	92.75	11.86	104.61
Laminator	0	5.13	5.13
Total	**112.06**	**87.70**	**199.76**

Table 6.7. Comparison of active and inactive modes and electricity used during November 2013

When the active and inactive modes of the machines used for printing are compared the use of electricity in the active mode is only 10.1% of the total units of electricity used. Using the data from Table 6.7 and the UK figure for CO_2 generated by 1kW, the CO_2 emission from each machine in Blue Apple Printing can be calculated. In the **UK 1kWh of electricity = 0.43 kg /CO_2.** This is shown is table 6.8. The total amount of electricity used by the machine used in Blue Apple Printing is 199.76 kWh, which yields 85.90kg of CO_2 into the atmosphere to contribute to environmental problems such as global warming. Hence, the annual CO_2 emissions for 2013 from the machines can be estimated by multiplying the monthly figure by a factor of 12 giving an annual value of 1,030.80kg (Chwalowski, 1996).

However this amount of CO_2 generated by using electricity fossil fuels can be prevented from damaging the environment by using solar energy.

Machine used	**Total Electricity used (kWh)**	**CO_2 produced (kg)**
Large format printer	20.18	8.6774
Photocopier 1	16.81	7.2283
Photocopier 2	9.29	3.9947
Document Centre	31.13	13.3859
Guillotine	12.61	5.4223
Heat Press	104.61	44.9823
Laminator	5.13	2.2059
Total	**199.76**	**85.8968**

Table 6.8. Total electricity used by each machine and amount of CO_2 released into the atmosphere in November 2013

6.3.5 Overall electricity used by Blue Apple Printing and its relationship to CO_2 emissions

The overall electricity consumed can be obtained from the meter readings and shown in table 6.8 which shows that in 2013 the units used were 5337 kWh and the amount of CO_2 emissions produced was 2,294.91 kg. The amount estimated from the usage of machines consuming electricity was calculated to be 1,030.80kg. Hence, the machines produced 44.9% of the total CO_2 emissions released into the atmosphere. The rest of the emission must be due to other fixed uses of electricity such as heating, lighting, kettle, computer and other miscellaneous uses (Ge and Tassou, 2014).

Month	Units Used (kWh)	CO_2 (kg)
Jan	355	152.65
Feb	367	156.52
Mar	532	228.76
Apr	574	246.82
May	461	198.23
Jun	426	183.18
Jul	427	183.61
Aug	404	173.72
Sep	460	197.80
Oct	543	233.49
Nov	416	178.88
Dec	372	159.96
Total	**5337**	**2293.62**

Table 6.9. Amount of electricity used each month in 2013 and associated CO_2 emitted into the atmosphere

6.3.6 Investigation of the use of silicon and flexible organic solar cells to replace fossil fuels in UK and Iraq

Using the approach the previous approach the amount of electricity generated from silicon solar cells and flexible organic solar can be calculated (Perkins, 1968). The Blue Apple Printing has a roof area available for silicon solar of 6m^2. It also has a window area of 8m^2 available for flexible organic solar cells when developed in the near future as a see through film that can be placed on windows.

The 20% silicon solar cells when placed on the roof will generate 4.8kWh per day in the UK and 14.4 kWh per day in Iraq. Assuming that electricity not used immediately could be stored and used when required then annually 1,752 kWh and 5,256 kWh of electrical energy could be generated. This equates to 32.8% of the electricity requirements of the Blue Apple Printing in UK and a reduction in CO_2 emissions of 753.36 kg into the atmosphere annually. In Iraq however where there is more sunlight then the 20% efficient solar cells in an equivalent printing business could replace 98.5% of its energy requirements and a reduction in CO_2 emissions of 2,733 kg of CO_2 using a conversion of 1 kWh = 0.52 kg of CO_2.

Flexible organic solar cells are predicted to make solar technology more accessible (Shirland, 1966). Currently, however the efficiencies of these solar cells are only around 5%, they degrade with heat and pollution in the environment. It is expected that as materials develop there will be an increase in the efficiencies and robustness of flexible organic cells (Al-Mohamad, 2004). This will enable them to be used on windows and surfaces non-obtrusively and generate additional electricity for use in business and domestic applications. Hence, more of the energy requirements currently served by fossil fuels will be met with solar energy.

6.3.7. Storage of excess solar energy

Solar cells do not produce electricity at night and when they become more efficient then excess electricity will be produced. There are several methods of storage the generated from solar panels (Whitacre et al., 2012). The most common one is to use a battery stack off grid or feed it back to the national grid. The off grid systems are very useful in rural areas and for poor communities where there is no supply of electricity. Currently, lead acid batteries are used but they are toxic and require air conditioning to avoid deterioration in some climates. Research is being carried to develop batteries from cheaper and natural materials that can generate 200 MW-hr (Parfomak, 2012).

CASE STUDY TWO

ANALYSIS OF KANSAS FRIED CHICKEN

6.4 Introduction

In this chapter a fast food outlet has been studied (Wolde-Ghiorgis, 1991). An approach similar to the previous business was taken. Electricity utilisation was investigated by taken measurements of the times of each electrical appliance was used was measured and the power rating were used to calculate the amount of electricity used over a period of time. Analysis was carried out using the same analysis programs used in the previous chapters. The proportion of electricity that could be replaced by solar energy was determined. The amount of CO_2 that entered the atmosphere was also calculated (Priambodo and Kumar, 2001).

6.5 Data collection and methodology

An approach similar to the one used in previous chapters was used.

6.6 Results and discussion

6.6.1 Analysis of Kansas Fried Chicken

Kansas Fired Chicken data regarding the opening days, units of electricity consumed and the costs was collected and analysed (Carlsson-Kanyama and Faist, 2000). This data is shown in table 6.10. The data obtained was normalised to enable a comparison of the trends.

Month	Units (kWh)	Cost (£)	Days Open	Normalised Units	Normalised Costs	Normalised Days open
Jan	4580	680.59	31	0.7372	0.7271	1.0191
Feb	5120	760.84	29	0.8241	0.8128	0.9533
Mar	6520	966.55	31	1.0495	1.0326	1.0191
Apr	6802	1010.56	30	1.0949	1.0796	0.9862
May	6789	1015.09	31	1.0928	1.0845	1.0191
Jun	6190	926.68	30	0.9963	0.9900	0.9862
Jul	5580	833.59	31	0.8982	0.8906	1.0191
Aug	4890	783.53	31	0.7871	0.8371	1.0191
Sep	6332	998.48	30	1.0192	1.0667	0.9862
Oct	6450	1012.91	31	1.0382	1.0821	1.0191
Nov	6949	1092.83	30	1.1185	1.1675	0.9862
Dec	8350	1150.64	30	1.3440	1.2293	0.9862
Sum	**74552**	**11232.29**	**365**			
Mean	**6212.67**	**936.024**	**30.42**			
Min	**4580**	**680.59**	**29**			
Max	**8350**	**1150.64**	**31**			

Table 6.10. Data for days open, total number of units and cost of electricity used

The number of days Kansas Fried Chicken was open has been plotted in figure 6.10. This food business is open 7 days a week except Christmas day. Hence, the business is open maximum possible days in the year. There is only a variation of 2 days throughout the year.

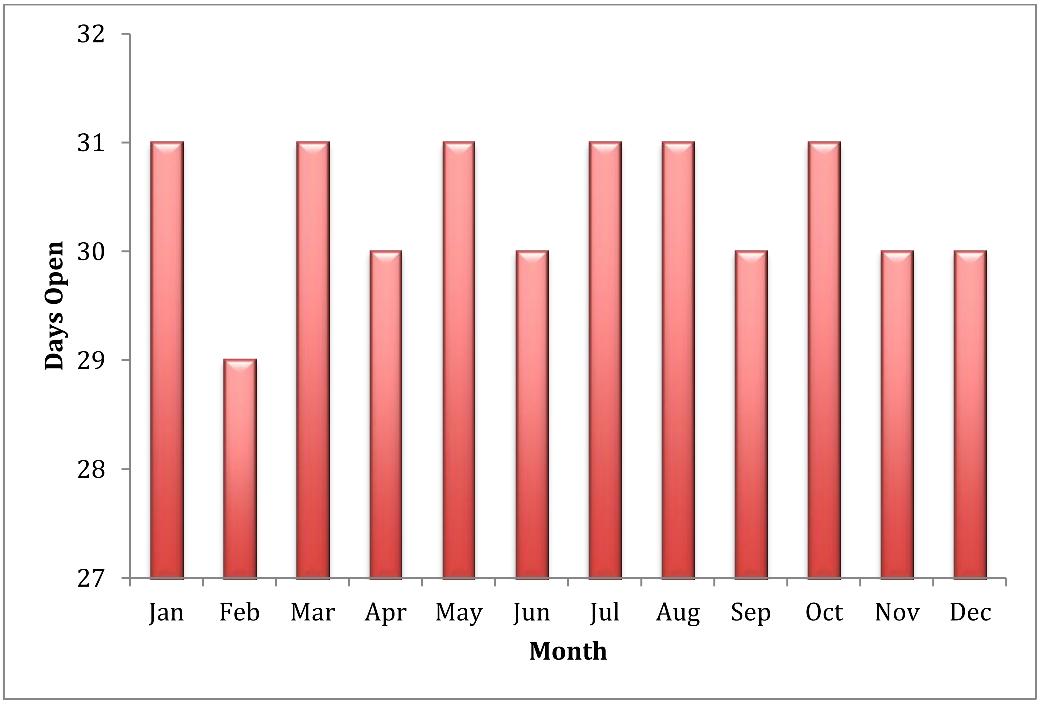


Figure 6.10. Opening days for Kansas Fried Chicken in 2012

The number of units of electricity used was analysed and plotted in figure 6.11. There appears to be no correlation between the units used and the days the outlet is open. This relationship is examined closely by plotting normalised data.

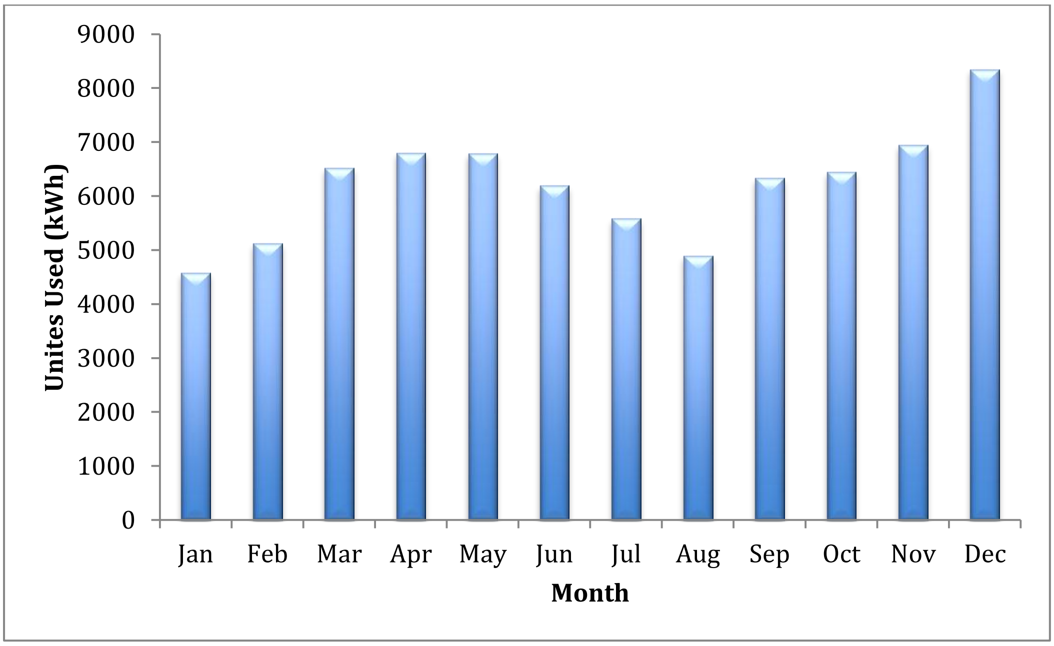


Figure 6.11. Units of electricity used during the months in 2012

The relationship between number of days open and units of electricity used is examined in figure 6.12. Clearly there is no relationship between the number of days open and the units of electricity used.

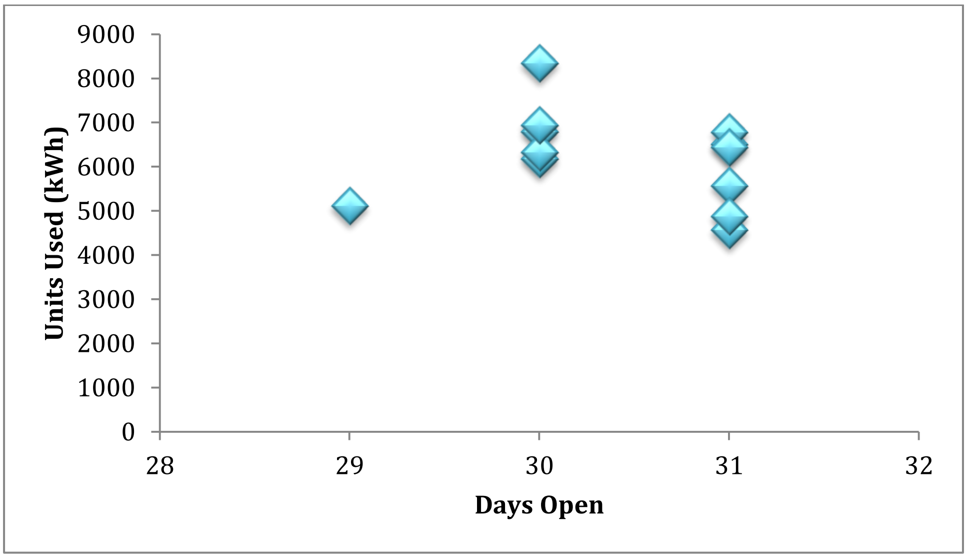


Figure 6.12 Units of electricity used and number of days open

The three variables were examined by plotting normalised values on the same graph to see if trends are similar. This plot is shown in figure 6.13.

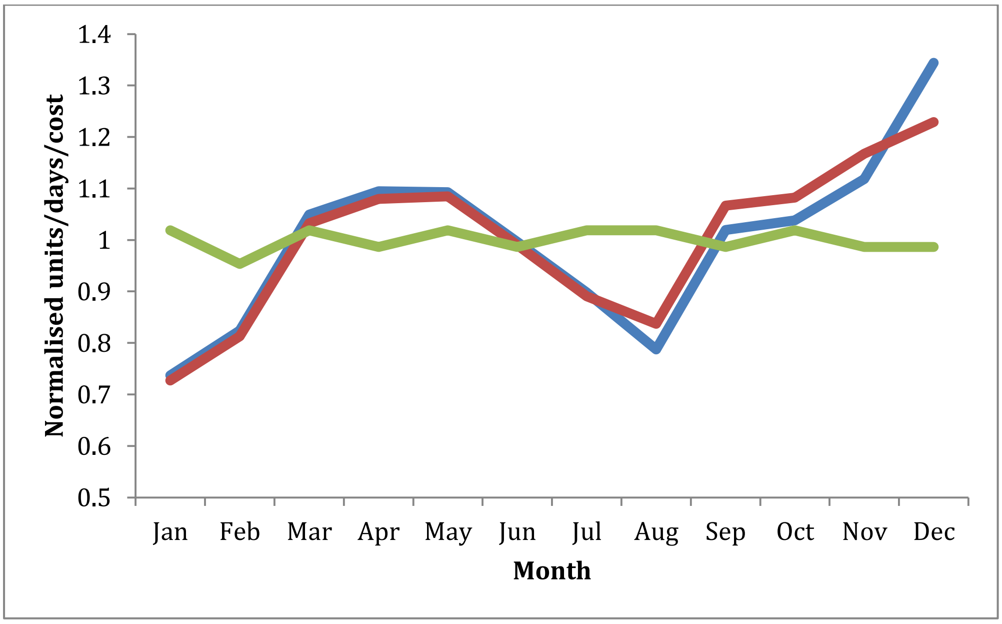


Figure 6.13 Normalised plots of days open (green line), units used (blue line) and costs (red line)

The number of days the Kansas Fried Chicken is open is fairly constant throughout the year with a variation of about 2 days, which reflect the calendar in 2012. When the units used and costs are examined the two normalised lines are almost on top of one another indicating a direct and close relationship as expected (David Pimentel, 1973). This was confirmed by plotting cost again units used. A linear trend line is indeed seen in figure 6.14

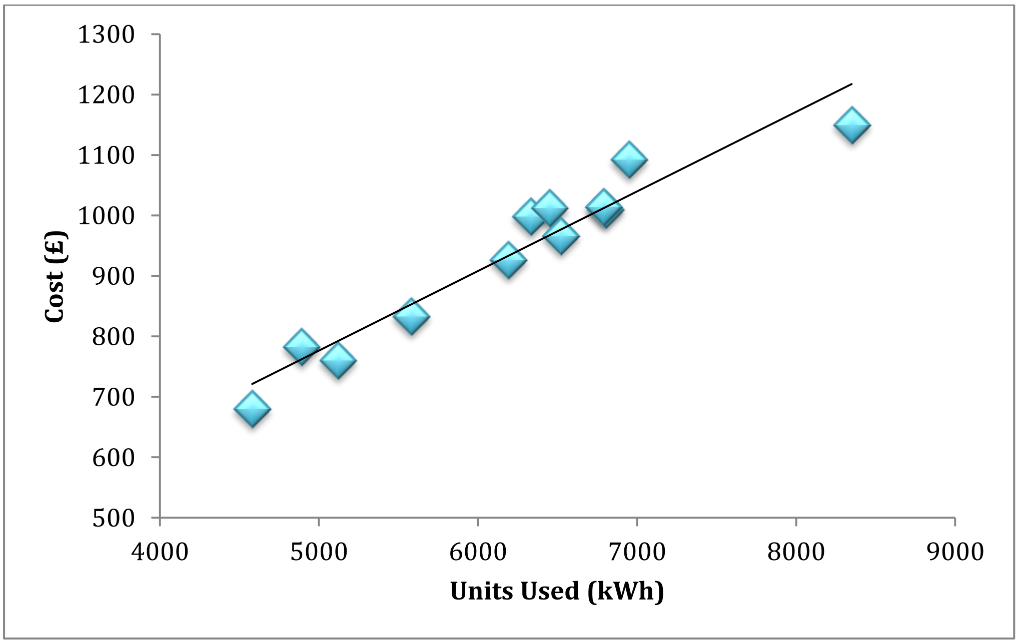


Figure 6.14. Relationship between costs and units of electricity used

6.6.2 Analysis of equipment use in Kansas Fried Chicken

Since Kansas Fried chicken was open all year except Christmas day, the weekly used was measured and annual calculation was done by multiplying by 52 weeks in the year. Unlike other businesses analysed in pervious chapter the equipment was switched on in the morning and left until the end of the day and switched off. The energy used was constant for equipment used.

Equipment	Power rating (kW)	Time (hr)	Electricity used (kWh)
Pressure fryer	11.25	57	641.25
Open fryer	2.49	80	199.2
Heated display	4.5	114	513
Breading table marinator	0.276	114	31.464
Wet heat bain marie	1	114	114
Heated chip scuttle	1.35	114	153.9
Cooler	0.23	114	26.22
Sum	**21.096**	**707**	**1679.034**
Mean	**3.013714286**	**101**	**239.862**
Min	**0.23**	**57**	**26.22**
Max	**11.25**	**114**	**641.25**

Table 6.11. Power rating, usage time of equipment and electrical energy used

The amount of electricity used by equipment is shown in figure 6.15. The pressure fryer used by far the greatest amount of electricity followed by heated display. This was used approximately 50% of the time and chip fryer about 70% of the time.

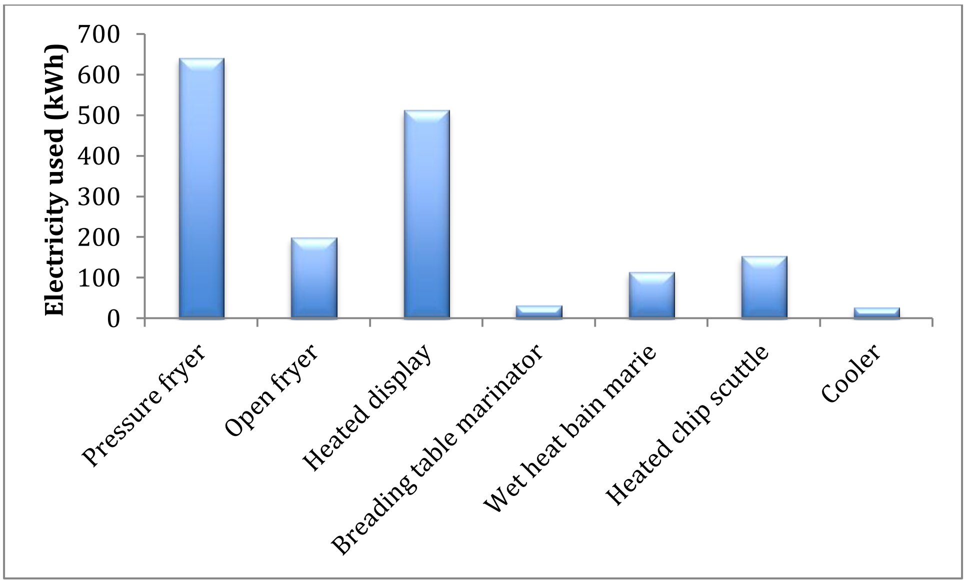


Figure 6.15. Electrical energy used by equipment in Kansas Fried Chicken

Since in this business there was little weekly variation these can be used to obtain the annual use readily by multiplying by 52. The electricity tariff is 13p per unit peak time and 7p per unit off peak. The average of these figures is 10p, which was used to estimate the amount of electricity used by equipment used to make and maintain food. The weekly amount of electricity used was 1679.03 kWh and at 10p per unit the electricity charge is £167.90 and therefore annual when multiplied by 52 gives £8,731.

When the actual electricity bill was considered it came to £11,232**.** The difference of £2501 between the amount of bill from the energy supplier and the figure calculated is due to fixed electricity costs of lighting, computer and other miscellaneous used.

6.6.3. CO_2 emission calculations from Kansas Fried Chicken

The approach used previously can be used again to calculate the CO_2 emissions generated by Kansas Fried Chicken by the equipment and overall business. The results are shown in table 6.12. The most CO_2 was generated by the pressure fryer and open fryer whereas the least by cooler.

Equipment	**Electricity used (kWh)**	**CO_2 (kg)**
Pressure fryer	641.25	275.7375
Open fryer	199.2	85.656
Heated display	513	220.59
Breading table marinator	31.464	13.52952
Wet heat bain marie	114	49.02
Heated chip scuttle	153.9	66.177
Cooler	26.22	11.2746
Total	**1679.034**	**721.98462**

Table 6.12. Amount of electricity used and CO_2 generated

The amount of CO_2 generated by Kansas Fried Chicken overall can be calculated from the units of electricity used in kWh and the CO_2 conversion factor for UK of 0.43. The overall figure is 32057.36 kg, which is 32 tons of CO_2 and if fossil fuels can be replaced with solar cells then this could be prevented from entering the atmosphere.

6.6.4 Replacing fossil fuel source of electricity with solar power

Using the same approach as in previous two chapters we can calculate the proportion of fossil fuels that can be replaced with silicon solar cells. This scenario can be extended to Iraq since similar fried chicken place also exist.

For 20% efficient silicon solar cells and an area of 6 m^2 the amount of solar energy generated can be calculated. In UK 4.8kWh per day can be generated whereas in Iraq with more favourable weather conditions 14.4 kWh per day can be generated. The annual figure is 1,752 kWh in the UK and 5,256 kWh in Iraq.

Kansas Chicken requires 74,552 kWh annual for its operation. Therefore, solar cells at their current rate of efficiency can replace only 2.4% of its annual requirement in the UK. However, in Iraq 7.1% of the energy requirements can be replaced by solar energy. These percentages can be increased as more of the surface area becomes amenable to flexible organic solar in the future as they become more efficient and robust. Kansas Fried Chicken and indeed other fast food place use a lot of energy for cooking and heating purposes and major developments in solar cell technology are required in terms of the improvements in efficiency and robustness of the cells used. The amount of CO_2 that can be saved from entering the atmosphere in UK is 769.38 kg whereas in Iraq we can prevent 5,293.19 kg from entering the atmosphere. This equates to 5 x less pollution when used in Iraq compared to UK die to more sunshine and daylight.

CASE STUDY THREE

ANALYSIS OF KIP MCGRATH EEDUCATION CENTRE

6.7.1 Introduction

In this chapter an education centre located in Bradford North is analysed (Huang, 2009). This centre is part of a multinational franchise. This company has several hundred centres in the UK (Foxon et al., 2008). A similar number of centres exist in New Zealand, Australia and others are scattered around the world. The company uses a blended learning approach with computers and traditional approaches for Maths and English. The lessons involve teaching five children at a time in 80 minutes sessions.

6.7.2 Methodology

The equipment using was noted to include 10 computers, 3 electric heaters, lighting, kettle, printer etc. Their power ratings were noted along with their usage. The amount of electrical energy used was calculated.

6. 7.3 Results and discussion

6.7.3.1 Analysis of equipment used for education purposes

The education centre uses simple equipment, which does not include intensive energy utilisation. It requires simple office equipment for its operation (Wasilewski et al., 2012). The weekly electrical energy used is given in table 6.13.

Equipment	Power rating (kW)	Weekly time (h)	Electricity used (kWh)
Computer 1	0.27	20	5.4
Computer 2	0.27	20	5.4
Computer 3	0.27	20	5.4
Computer 4	0.27	20	5.4
Computer 5	0.27	20	5.4
Computer 6	0.27	20	5.4
Computer 7	0.27	20	5.4
Computer 8	0.27	20	5.4
Computer 9	0.27	20	5.4
Computer 10	0.27	20	5.4
Printer 1	0.25	5	1.25
Printer 2	0.25	5	1.25
Sum	**3.20**	**210**	**56.50**
Mean	**0.27**	**17.5**	**4.71**

Table 6.13. Equipment, power ratings and electrical energy used per week

The annual electricity consumption for equipment used to delivery educational programmes over the 40 weeks the centre is open is 56.50 x 40 = 2260 kWh. The annual cost is thus given by assuming 2260 x 20p per unit is £452.00 for computers and printers used.

The number of days open during the year 2012 is given in table 6.14. The daily use of electrical energy with heating, lighting and small appliances gives 2585.6/202 = 12.8 kWh opening 4 hours a day and using an average of 3.2 kWh from Table 6.13. Hence, the overall amount of electricity used in 2012 is 2585.6 kWh equating to annual amount at 20p per KWh to be 2585.6 x 20p = £517.12.

Hence, 2585.6kWh/202 days = 12.8kWh per day and therefore using number of days open for January for example gives 12.8 kWh per day x 21 days = 268.8 kWh and repeated for the year 2012 (see Table 6.14).

Month	Days	Electricity used (kWh)	Normalised days	Normalised electricity
Jan	21	268.8	1.2478	1.2475
Feb	14	179.2	0.8318	0.8317
Mar	22	281.6	1.3072	1.3069
Apr	14	179.2	0.8318	0.8317
May	23	294.4	1.3666	1.3663
Jun	21	268.8	1.2478	1.2475
Jul	14	179.2	0.8318	0.8317
Aug	0	0	0	0
Sep	20	256	1.1884	1.1881
Oct	23	294.4	1.3666	1.3663
Nov	15	192	0.8913	0.8911
Dec	15	192	0.8913	0.8911
Total	**202**	**2585.6**		
Mean	**16.83**	**215.47**		

Table 6.14. Days centre was open in 2012 and electricity used

The data is plotted in figure 6.16 below.

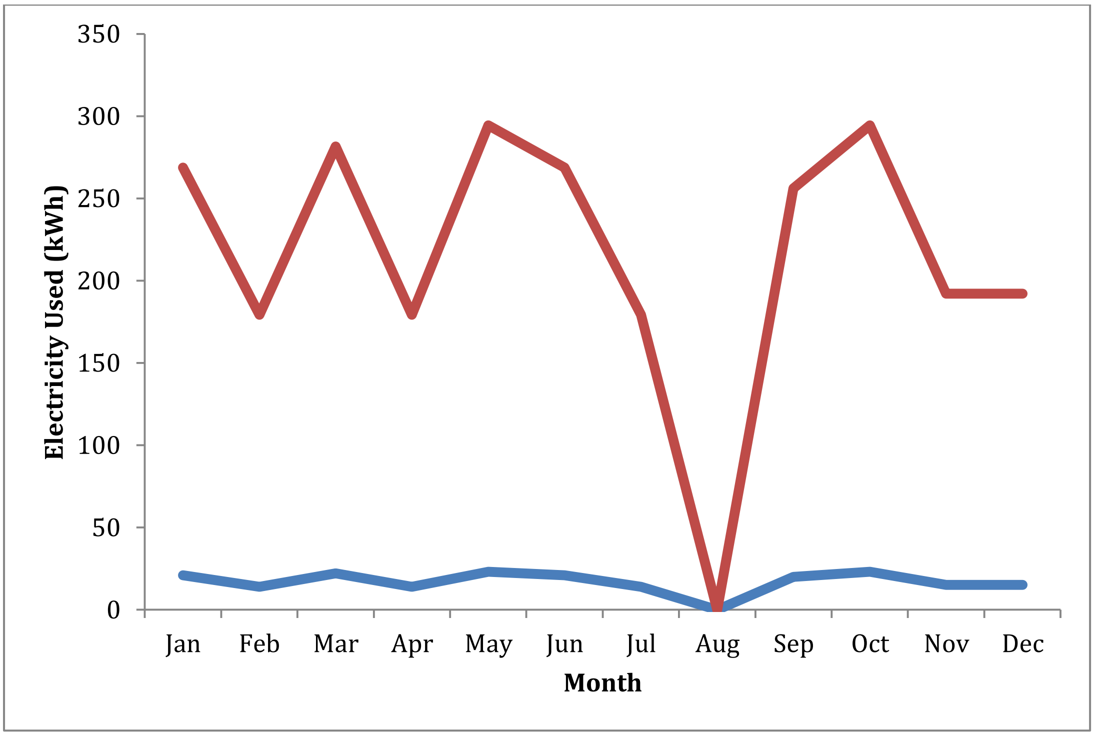


Figure 6.16. Plot of electricity used and days the centre is open

To explore the relationship between the number of days open and electricity the data was normalised and plotted on to of one another. A direct relationship is postulated. The plot is identical hence shown as a bar chart to illustrate.

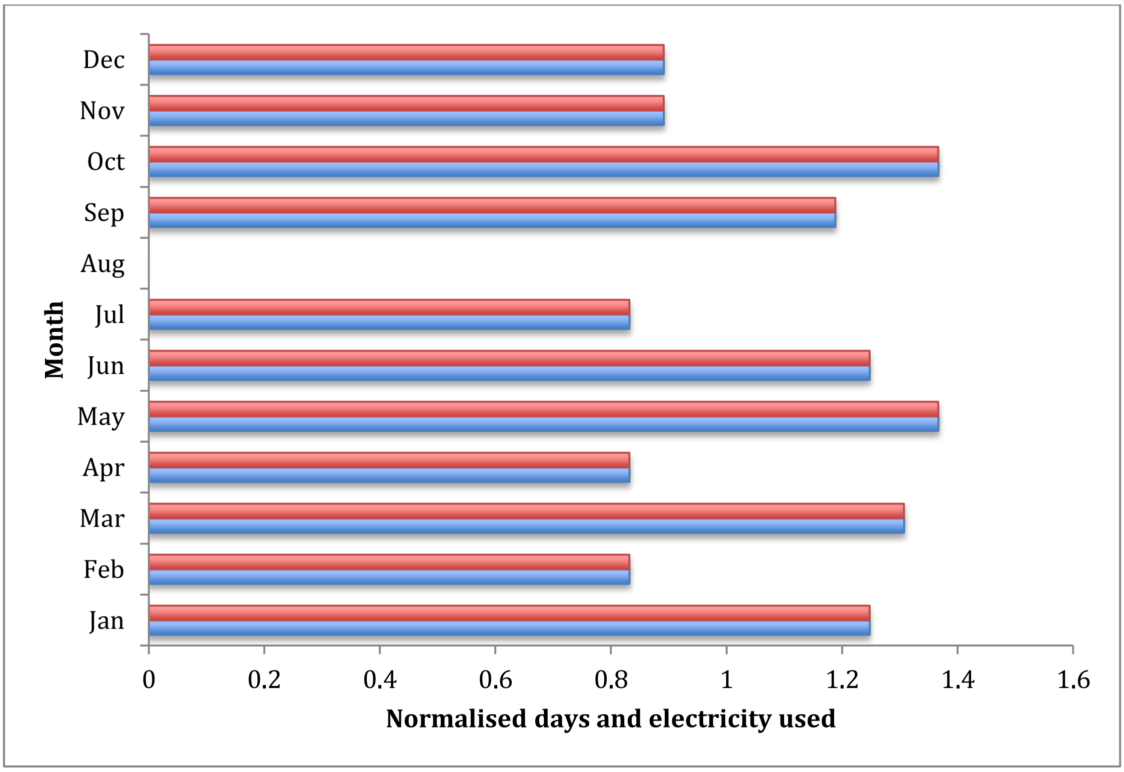


Figure 6.17. Normalised values of days open (blue line) and electricity used (red line). The zero value in August indicated that the centre was closed

The relationship between the electricity used is dependent in the number of days the centre opened. This is shown in figure 6.18. Clearly there is a strong positive correlation between these two parameters as expected.

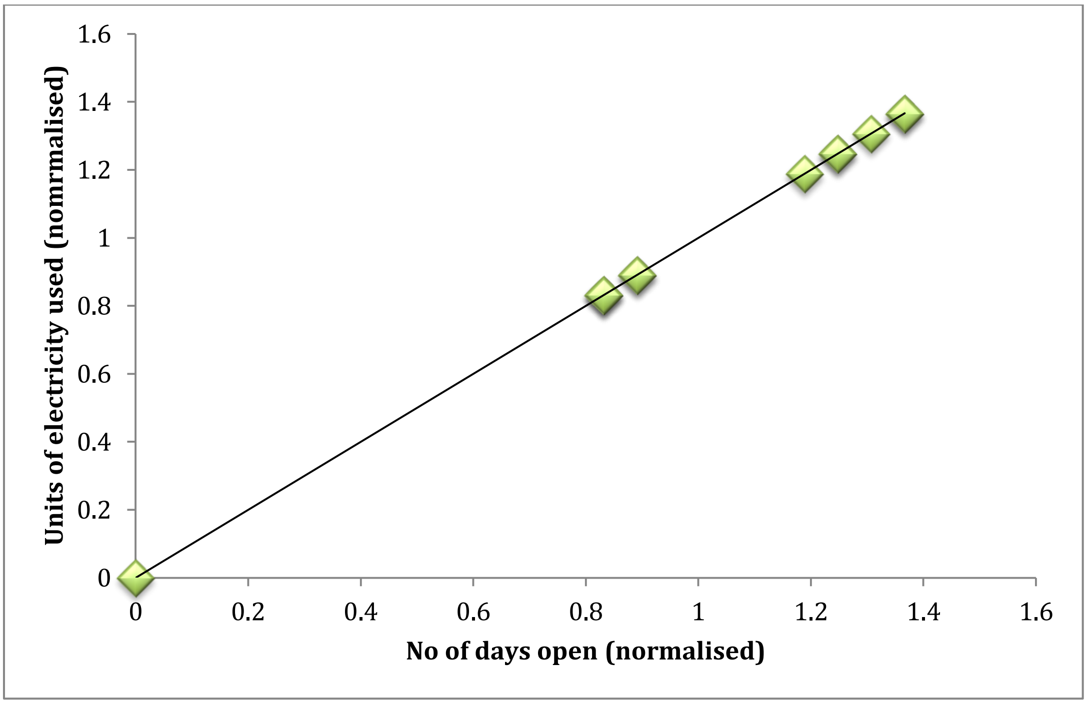


Figure 6.18. Relationship between the amount of electricity used and the number of days a centre is open during the months of the year.

From the electricity bill the units used per annum were 3085 kWh and at 20p per unit the cost is £617.00. The difference between this value (£617) and the value of £517.12 calculated for 10 computers and printers of £99.88 is due to the cost of heating, lighting and computers in inactive modes when the centre is not open. There may be a very small element of using small appliances such as kettle, microwave and fridge.

In the final analysis the computers and printers use relatively small amount of electricity. In Kurdistan instead of heating the climate requires the use of air conditioning.

The education centre is located on a small shop premises with potentially an equivalent area of solar panels.

The CO_2 emission from Kip McGrath Education Centre can be calculated. In the **UK 1kWh of electricity = 0.43 kg /CO_2.** The total amount of electricity used annually is

3,085 kWh, which yields 1,326 kg of CO_2 into the atmosphere to contribute to environmental problems such as global warming. For same of electricity used in Kurdistan using a conversion 1kWhr = 0.52 gives 3085 x 0.52 = 1,604 kg / CO_2 produced.

The amount of electricity generated from silicon solar cells and flexible organic solar can be calculated. The Kip McGrath Centre has a roof area available for silicon solar of $6m^2$. It also has a window area of $8m^2$ available for flexible organic solar cells that can be placed on windows.

The 20% silicon solar cells when placed on the roof will generate 4.8kWh per day in the UK and 14.4 kWh per day in Iraq. Assuming that electricity not used immediately could be stored and used when required then annually 1,752 kWh and 5,256 kWh of electrical energy could be generated in UK and Iraq. Kip McGrath used 3,085 kWh kWh annually in 2012 hence 1,752/3085 kWh multiplied by 100 gives the percentage of electricity that can be replaced by solar energy which equates to 57%. However, in Kurdistan Iraq the value calculated 5256/3085 kWh multiplied by 100 gives 170%. As expected, Kurdistan is better suited for using solar energy to replace fossil fuels than UK. If the surplus energy was fed back into the grid then a handsome profit margin is achieved.

6.8. Conclusions

Considering the analysis of the four SMEs it was found that the most energy intensive business was fried chicken using a large amount of electricity due to heavy heating equipment and the least energy intensive business was the education centre, which uses computers and printer. In the latter in UK 57% of the electricity usage could be replaced by solar energy compared to Kurdistan, which generated a surplus energy that could be fed into the national grid. The gents groom hairdressing and blue apple businesses intermediate figures were obtained. Therefore, also parallel conclusion drawn regarding CO_2 emissions released into the atmosphere with education centre being the most environmentally friendly and the fried chicken the least.

CHAPTER SEVEN

VARIATION COMPARISONS OF SOLAR INSULATION IN THE UK AND IRAQ USING HYPOTHESIS TESTING

7.1. Climate and weather Northern Iraq and United Kingdom

Kurdistan is located in the northern region of Iraq and operates autonomously. The region comprises of Erbil, Slemanyah and Duhok areas. Kurdistan has borders with Iran to the east, Turkey to the north and Syria in the west. It has an area of 40,643 km^2 with a population of 3,757,058. It has mountains with average height 2,400m rising to 3,3600m in places (Berger et al., 2003).

Figure 7.1. Geographical map of Kurdistan region. Adapts from :http://www.fao.org/ag/agp/AGPC/doc/Counprof/Iraq/Iraq.html

Kurdistan has extreme continental climate being very hot and dry in the summer and bitterly cold and wet in the winter with an annual rainfall of 375-724 mm. The land is fertile with grain and livestock being exported. The average high temperatures range from 13-18 degrees in March to 27-32 ^{o}C in May. In the summer months from June to September are very hot and dry. In July and August, the hottest months, mean highs are 39-43 ^{o}C often reaching 50 ^{o}C. Autumn is dry and mild, and like spring is an ideal time of year to travel in the Region. Average temperatures are 24-29 ^{o}C in October, cooling slightly in November. Winters are mild, except in the high mountains. Mean winter high temperatures are 7-13 ^{o}C, and mean lows are 2-7 ^{o}C (Mills, 2013).

England comprises of 2/3rd of the British Isles including several islands such as Isle of White and Isle of Scilly. The south is made of green hills. The east and north of England is flat and low lying. The coastline is varied, with northern England's coast made up mainly of flat sand dunes. In the North the landscape has mountain ranges of the Yorkshire Dales and Lake District in the northwest afford picturesque views of valleys, lakes, forest and mountains, making both destinations popular with hikers. Pennines range bisects the northern region, creating a natural divide between the North West and North East. Traversed by the Pennine Way (Semenov, 2007).

England has warm wet summers and cool wet winters varying from day to day and throughout the country with the west coast and mountainous areas receiving the most rain. Winter is from late October to early March. The east coast is colder and windier with winds blowing in from Siberia. Heavy snow can cause problems with transport Temperatures have hit -5°C (23°F) during winter but temperatures below this are very rare. Summer is from May to early September with the southeast being sunnier than the north, with less rain and a continental type climate. In the summer, the temperatures can reach 30°C with the southwest having the mildest climate (Wilby and Perry, 2006).

Figure 7.2. Geographical map of England. Adapts from : http://www.mapsofworld.com/united-kingdom/

7.2. Forming the Hypothesis

One of the most important applications of statistics is to use a sample to test an idea, or hypothesis regarding the population. This is generally known as statistical inference (Rao, 2009). Conclusions can never be absolutely certain but the risk of your conclusion being incorrect can be quantified (measured) and can enable you to identify statistically significant evidence to suggest they are incorrect.

In any experiment you will have your own idea or hypothesis as to how you expect the results to turn out. In our study on solar energy output potential, an important parameter is the amount of sunlight hours or solar insolation available in the region and country of interest (Casella and Berger, 2002).

We begin with a **null hypothesis**, $\mathbf{H_0}$ at the start which is a statement which defines the population. Usually, you are hoping to show that the null hypothesis is **not** true and so the **alternative hypothesis**, $\mathbf{H_1}$ is often the one you want to establish. The null hypothesis is only abandoned in the face of overwhelming evidence that it cannot explain the experimental results.

To summarise then,

$\mathbf{H_0}$: states that the situation is unchanged, that a population parameter takes its usual value.

$\mathbf{H_1}$: states that the parameter has increased, decreased or just changed.

7.3. Hypothesis Methodology

We will be considering a **two-tailed** test see figure 7.3. A two-tailed test is one where $\mathbf{H_1}$ involves testing for any (non-directional) change in the parameter (Steel and Torrie, 1960). In our study we are interested in seeing if there is the same amount of solar insolation falling in all regions of the U.K and Iraq as we 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 insolation is expected.

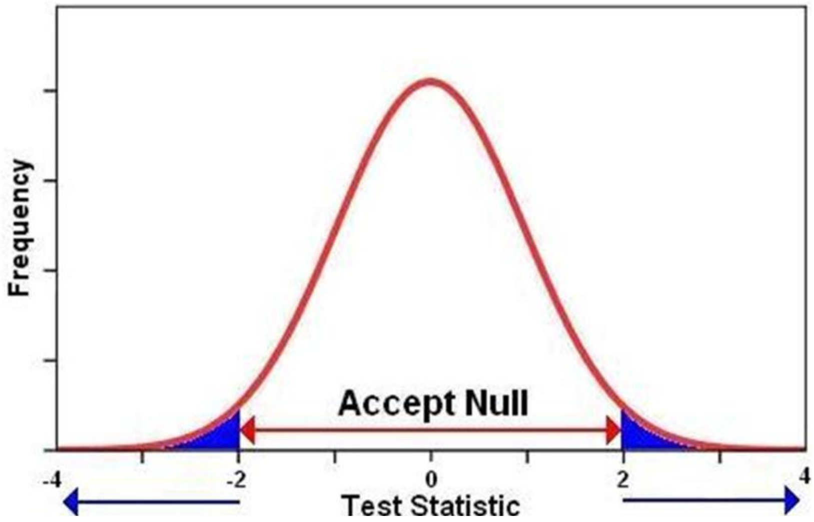


Figure 7.3. Choosing when to Accept and when to Reject the Null Hypothesis

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, we must also use an estimate (s) for our (σ) given by:

$$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}} \qquad \text{Eq. 7.1}$$

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:

$$\frac{\bar{x} - \mu}{s/\sqrt{n}} \qquad \text{Eq. 7.2}$$

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 insolation 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 insolation is the same in all regions of the country (latitudinally) as the most southern region.

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

7.4. Solar Insolation Data for Six Cities in Iraq and U.K

Our data (Aziz, 2013) for the daily average solar insolation in kWh/m^2/day for both Iraq and the U.K for six different cities is shown in the tables 7.1 and 7.2 below.

IRAQ:

Table 7.1: Average daily solar insolation per month (kWh/m²/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 7.2: Average daily solar insolation per month (kWh/m²/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
Total	**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**					

7.5 Calculations and Results

For IRAQ:

H_0 : μ = 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.

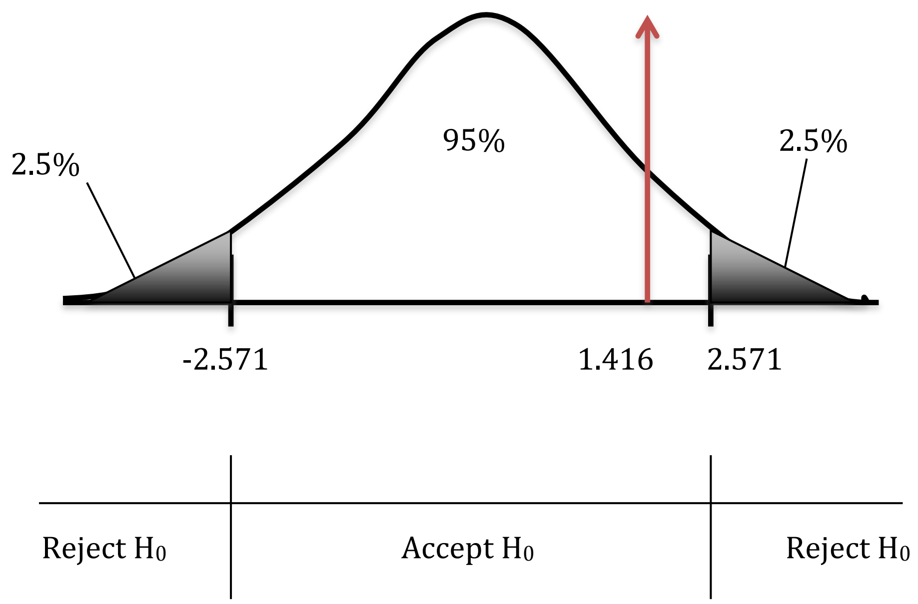
From the **t – distribution** tables the critical values are found as **t = $\pm$ 2.571**

Using 7.1 and 7.2.

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



$$\boldsymbol{n = 6 \text{ so } df = 5 \text{ and } p = 0.975}$$
$$\mathbf{t}_{\frac{\alpha}{2},n-1} = \mathbf{t}_{0.025,5} = \pm 2.571$$

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

For U.K.

$\mathbf{H_0 : \mu = 3.40}$

$\mathbf{H_1 : \mu \neq 3.40}$

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.

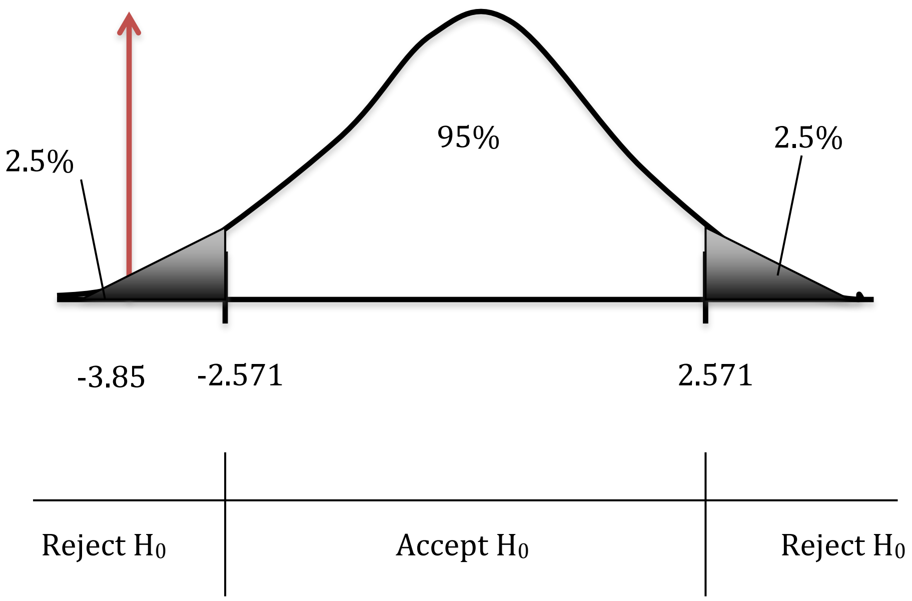
From the **t – distribution** tables the critical values are found as **t =** $\pm$ **2.571**

Using 7.1 and 7.2.

$s = \sqrt{\frac{\sum(x - \bar{x})^2}{n-1}}$ and the test statistic as $\frac{\bar{x} - \mu}{s/\sqrt{n}}$, the data points for Iraq

give

$\bar{x} = 2.96$ and $s = 0.280$ implies that the **test statistic = - 3.85**.



$$\boldsymbol{n = 6 \text{ so } df = 5 \text{ and } p = 0.975}$$
$$\mathbf{t}_{\frac{\alpha}{2},n-1} = \mathbf{t}_{0.025,5} = \pm 2.571$$

Since $-3.85 < -2.571$, hence $\mathbf{H_0}$ is **rejected,** there is significant evidence to suggest that the average solar insolation 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 insolation available.

7.6. Conclusions

To show that solar energy is a viable alternative to conventional energy sources one of the most important parameters with the use of solar panels is the amount of solar insolation potential available in that region and country of interest.

If there is a constant high amount of solar insolation available in the country then implementation and use of solar panels is a viable option and makes sense. If there are significant fluctuations in the amount of solar insolation within the different regions of a country then more serious consideration has to be given before implementation occurs.

What is seen from our data and statistical inference calculations is that in Iraq over all the regions (latitudinal) on average the amount of solar insolation is close to the hottest region. There is a reasonably constant amount of solar insolation 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 insolation 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 insolation 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 insolation in all regions of the country throughout the whole year are very good places to use solar energy as an alternative source. Countries like the U.K we need to see more closely the data on solar insolation and look at the cost analysis to see if implementation is appropriate in the different regions of that country.

CHAPTER EIGHT

CONCLUSIONS AND FUTURE WORK

8.1. Conclusions

This work studied the energy utilization in four SME type businesses as outlined in the aims and objectives by analyzing the various components and appliances used in the businesses. The feasibility of replacing the energy from fossil fuels with solar cells was investigated with each of the businesses analysed. Each business is a public places with its own distinct features and existed in different categories. As stated in the objective specific businesses included a hair dressing salon, take away franchise, education centre and printing business. In addition a larger public place Sulemanyah Airport in Kurdistan was also included in the study. The amounts of CO_2 released by each of these businesses were also determined. These gases cause global warming resulting in long-term damage to the planet. The feasibilities of replacing fossil fuel source of energy with conventional silicon and organic solar cells were investigated and the proportion of the total energy untilisation that can be replaced by solar energy was calculated. This was correlated with the amount of CO_2 reduction possible with use of solar energy. As stated in the objectives, a country wide comparison six cities in UK and Kurdistan were chosen for analysis. When using solar energy as an environmentally friendly alternative to fossil fuels the climatic and geographical locations of Kurdistan and England were compared as stated in the objectives.

Kurdistan has a good number of sunshine hours per day and is ideal places for harnessing solar energy available from the sun. Micro-businesses in Kurdistan have potential for replacing a large proportion of its electrical energy needs with solar energy. Combined the impact is significant in terms of carbon, Iraq. A solar plant with a capacity to generate around 7.3% of the airport's yearly demand was found to have a potential to reduce the carbon dioxide emissions by 0.28 million kilograms a year. Over a period of the average life span of a solar photovoltaic system of twenty years, this gives rise to huge saving in CO_2 emissions in the region of 5.6 million kilograms. However, initial investment costs of setting up such a plant are incurred; however over the average life span of the solar plant almost half of the initial costs would be recovered whilst reducing greenhouse effects.. Use of multiple solar plants throughout the country can have a major impact on overall CO_2 emissions. The use of solar energy is a viable option in certain remote regions as well as in developing countries as these systems can be set up as stand-alone operations without the need for a national grid structure. Continuous reduction in costs and increasing efficiencies in solar PV technology this method of energy generation has huge potential both for being environmentally friendly and as an energy source for SME's and larger facilities like airports.

Groom Gents Hair Salon was used as an initial business to develop the analysis. Each tool was analysed and related to energy consumed during operation and related to the overall energy input. The daily energy utilized was converted to annual usage and a relationship between energy utilization and carbon emissions was established. The feasibility of replacing the energy demand with solar cells was explored. If solar energy was implemented then significant carbon emissions would be prevented from entry into the atmosphere. For this business unit predictions were made regarding the future use of flexible solar cells and how these would further reduce carbon emissions. Other SMEs businesses were also analysed and it was demonstrated that a significant proportion of their energy utilized may be replaced with solar power hence reducing harmful effects on the environment.

To show that solar energy is a viable alternative to conventional energy sources one of the most important parameters with the use of solar panels is the amount of solar insolation potential available in that region and country of interest.

If there is a constant high amount of solar insolation available in the country then implementation and use of solar panels is a viable option and makes sense. If there are significant fluctuations in the amount of solar insolation within the different regions of a country then more serious consideration has to be given before implementation occurs.

Analysis of the four SMEs showed that the most energy intensive business was fried chicken take away using a large amount of electricity and the least energy intensive business was the education centre,. In the latter in UK 57% of the electricity usage could be replaced by solar energy compared to Kurdistan, which generated a surplus energy that could be fed into the national grid. The gents groom hairdressing and blue apple businesses gave intermediate figures. Parallel conclusions were drawn regarding CO_2 emissions released into the atmosphere with education centre being the most environmentally friendly and the fried chicken the least.

Data and statistical inference calculations show that in Iraq over all the regions (latitudinal) on average the amount of solar insolation is close to the hottest region. There is a reasonably constant amount of solar insolation in the different regions of the country. However, the analysis for U.K shows significant evidence to suggest that the amount of solar insolation is not the same as the hottest region and further analysis is needed. When the data is examined further it indicates that the more northern regions of the U.K generally get less insolation 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 insolation in all regions of the country throughout the whole year are very good places to use solar energy as an alternative source. Countries like the U.K we need to see more closely the data on solar insolation and look at the cost analysis to see if implementation is appropriate in the different regions of that country.

In summary, the most viable solution at this stage of solar cell technology development is a hybrid solution where a proportion of the total energy could be replaced which could still have an important impact on the climate. This is more appropriate in the UK whereas in Kurdistan a far greater or almost all the fossil sources in some of the business could be replace with solar. For example, the education centre can operate exclusively on solar whereas in energy intensive take away enterprise such as Kansas Fried Chicken a hybrid solution is more appropriate.

8.2 Future work

This study could be extended to shopping centres containing multiple units or businesses and how much could be replaced by solar energy. These would have a greater impact combined compared to individual businesses on the cost, the energy utilization and environmental damage caused.

It would be interesting to carry out a global analysis and compare contrasting weather conditions of countries with abundant sunlight and with sparse daylight. The conditions need to be correlated closely with types and solar cells used and these would impact the lifetime of the cells and cost.

In this study predictions were made about energy untilisation using calculations and making assumptions of their efficiency and performance. It would be highly interesting to actually install solar panels, both conventional and organic flexible cells in the types of businesses investigated and compare actual results with theoretical results. It would also be informative to compare flexible organic solar cells with conventional solar cells.

An interesting study would be use software packages such as Witness to simulate various scenarios in large public places such as shopping complexes, hotels, sports stadiums and airports. Simple models of very small public places were constructed in this study, however the student version of Witness was highly limited and therefore the study was postponed for future work.

Investigate the impact of nanotechnologies on the solar efficiencies, size and output and their impact on the businesses and environment.

Energy has an impact on the business therefore an economic analysis of various renewable energy options would be highly informative.

The cultural environment and awareness of global warming and other damaging factors and various options also merits further investigation.

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APPENDIX A – PERCENTAGE POINTS OF STUDENT'S t-DISTRIBUTION

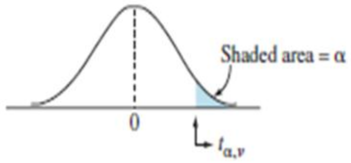

TABLE 2

Percentage points of Student's *t* distribution

df/α =	.40	.25	.10	.05	.025	.01	.005	.001	.0005
1	0.325	1.000	3.078	6.314	12.706	31.821	63.657	318.309	636.619
2	0.289	0.816	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.277	0.765	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.271	0.741	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.267	0.727	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.265	0.718	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.263	0.711	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.262	0.706	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.261	0.703	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.260	0.700	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.260	0.697	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.259	0.695	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.259	0.694	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.258	0.692	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.258	0.691	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.258	0.690	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.257	0.689	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.257	0.688	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.257	0.688	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.257	0.687	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.257	0.686	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.256	0.686	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.256	0.685	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.256	0.685	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.256	0.684	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.256	0.684	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.256	0.684	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.256	0.683	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.256	0.683	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.256	0.683	1.310	1.697	2.042	2.457	2.750	3.385	3.646
35	0.255	0.682	1.306	1.690	2.030	2.438	2.724	3.340	3.591
40	0.255	0.681	1.303	1.684	2.021	2.423	2.704	3.307	3.551
50	0.255	0.679	1.299	1.676	2.009	2.403	2.678	3.261	3.496
60	0.254	0.679	1.296	1.671	2.000	2.390	2.660	3.232	3.460
120	0.254	0.677	1.289	1.658	1.980	2.358	2.617	3.160	3.373
inf.	0.253	0.674	1.282	1.645	1.960	2.326	2.576	3.090	3.291

APPENDIX B

PEER REVIEWED PUBLICATIONS

SOLAR PHOTOVOLTAIC GENERATION POTENTIAL AND PLANT CAPACITY IN NORTHERN IRAQ.
Azad Azabany, Khalid Khan and Waqar Ahmed
Asian Journal of Science and Technology, Vol, 5, Issue 3, 2014, ISSN: 0976-3376

COST ANALYSIS OF A PHOTOVOLTAIC PLANT CONNECTED TO A 315KW SOLAR GRID IN ERBIL, KURDISTAN, IRAQ.
Azad Azabany, Khalid Khan and Waqar Ahmed
Asian Journal of Science and Technology, Vol, 5, Issue 3, 2014, ISSN: 0976-3376

REDUCTION IN CO_2 EMISSIONS FROM ELECTRICITY GENERATION FROM SOLAR ENERGY AT SULAYMANYAH AIRPORT IN KURDISTAN, IRAQ.
Khalid Khan , Azad Azabany and Waqar Ahmed
Asian Journal of Science and Technology, Vol, 5, Issue 3, 2014, ISSN: 0976 3376

ENERGY ANALYSIS FOR REPLACING FOSSIL FUEL ENERGY SOURCE OF ELECTRICITY WITH SOLAR CELLS IN THE UK AND KURDISTAN, IRAQ.
Azad Azabany, Khalid Khan, Waqar Ahmed and Mahmood H Shah
Asian Journal of Science and Technology
Vol. 5, Issue 9, pp. 541-545, September, 2014

COMPARISON ON THE USE OF SILICON AND FLEXIBLE ORGANIC SOLAR CELLS AS REPLACEMENTS FOR FOSSIL FUEL ENERGY SOURCE OF ELECTRICITY IN THE UK AND KURDISTAN,IRAQ.
Azad Azabany, Khalid Khan and Waqar Ahmed
Asian Journal of Science and Technology
Vol. 5, Issue 9, pp. 557-560, September, 2014