Renewable Energies Management Strategy Challenges in the Arabian Gulf Countries

A Thesis Submitted for the Degree of Doctor of Philosophy

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ABSTRACT

The main source of energy in the Gulf Cooperation Council (GCC) remains fossil fuels (oil and gas). The massive and accelerated used of such sources of energy not only depletes the traditional energy sources in those states and thus undermines exports and long-term prosperity; it also causes devastating damages to the environment and to human health.

The nature of the Arabian Peninsula is very suitable for renewable energy sources (RES), thus many GCC states have started to consider those resources for their future energy plans. Like any technology, renewable energy technologies (RET) face many challenges such as economic, technical, social and environmental.

This research analyses renewable energy (RE) possibilities and barriers in the GCC states in depth, using Kuwait as a case study. Questionnaires were distributed to three different groups to measure their attitudes and knowledge with regard to RE. Moreover, this research investigates the economic and environmental implications of RES adoption for Kuwait. A cost analysis between the traditional energy generated by the Ministry of Electricity and Water (MEW) using oil and gas, and RE energy generated by Al- Shagaya project has been carried out.

It was found that most participants were environmentally aware of fuel issues and supported RE; they were prepared to forego subsidies on traditional energy to promote RE, but they doubted the government's ability to implement RE successfully. Although Al-Shagaya Project was targeted to contribute up to 15% of Kuwait's total power production by 2030, the cost analysis presented in this thesis revealed that the energy generated from the Al-Shagaya Project accounts for only 2% the energy needs projected at 2030, therefore current plans would only reduce CO_2 emissions by 2% by 2030, but a program was proposed whereby larger investment would cause a 92% reduction in costs and reduce CO_2 emissions to zero within the same timeframe.

Key words: Kuwait, GCC, renewable energy, solar, wind, Al-Shagaya, fossil fuel dependence.

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ABBREVIATIONS

AC	Air Conditioner
AFFD	Arab Form For Environmental Development
ANOVA	Analysis of Variance
BIC	Bahrain International Circuit
BIPV	Building Integrated Photovoltaic
BOT	Build- Operate-Transfer
BP	British Petroleum
CCPI	Climate Change Performing Index
CDM	Clean Development Mechanism
COP	Convective Precipitation
CPV	Competitive Power Ventures
CSP	Concentrated Solar power
EPIA	European Photovoltaic Industrial Association
EU	European Union
FEA	Federal Environment Agency
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GW	Giga Watts
IEA	International Energy Agency
IMF	International Monetary Fund
IPCC	International Panel on Climate Change
IRENA	International Renewable Energy Agency
IRER	International Renewable Energy Research
JD	Jordanian Dinar
KACST	King AbdulAziz City for Science and Technology
KD	Kuwaiti Dinar
KPC	Kuwait Petroleum Corporation
KSA	Kingdom of Saudi Arabia
MEDRC	Middle East Desalination Research Centre
MEW	Ministry of Electricity and Water
MM	Millimetre
MMT	Million Metric Tone
MW	Mega Watts
NASA	National Aeronautics and Space Administration
NHS	National Health Service
NOP	National Opinion Polls
OECD	Organization for Economic Cooperation and Development
OPEC	Organization of the Petroleum Exporting Countries
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Resources
RERT	Renewable Energy Resources Technology
RET	Renewable Energy Technology
RUE	Rational Use of Energy
SD	Standard Deviation
SPSS	Statistical Product and Service Solutions

SPV	Solar Photovoltaic
TRE	Tozzi Renewable Energy
UAE	United Arab Emirates
UK	United Kingdom
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WWEA	World Wind Energy Association

DECLARATION

This work was produced by the author unless otherwise stated and duly acknowledged.

Signed: ……………………….

Date: ……………………….

CHAPTER 1: INTRODUCTION

1.1 Background

The Gulf Cooperation Council (GCC) was founded as the result of an agreement reached on the 25th of May 1981, in Riyadh, Saudi Arabia, amongst the following countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE) [1]. The primary objective of this unity is to establish and coordinate common policies and defence strategies between the GCC states. The six countries are located in the Arabian Peninsula, which is located between the Arabian Gulf to the northeast, the Strait of Hormuz and the Gulf of Oman to the east, the Arabian Sea to the southeast and south, the Gulf of Aden to the north, the Bab-el-Mandeb strait to the southwest, and the Red Sea to the west. The GCC countries share borders with Yemen in the southwest, Iraq in the northeast, and Jordan in the northwest (Figure 1.1). The GCC countries share a total area of 2,673,108 km^2 ranging dramatically in size from the large Kingdom of Saudi Arabia (KSA) with more than 27 million people, to the small Kingdom of Bahrain, with less than one million [2]. A large number of oil fields were discovered in those countries, some of which are considered the largest in the world [3]. Based on a report published by the US Geological Survey published in 2003[4], the region has undiscovered resources of crude oil estimated at 162 billion barrels, around 17% of the world total, and the untapped resources of natural gas in the region were estimated to be around 32.3 trillion cubic meters, around 16% of the world's total reserve [5]. At current rates, Oman could produce oil for another 21.3 years, Qatar for 62.8, KSA for 69.5, UAE for 91.9, and Kuwait for more than 100 years.

The economic growth of modern societies today is mainly dependent on energy supplies. Oil and gas generate 57% of the commercial energy supplies worldwide, most of which are produced by the GCC countries. However, the burning of such sources of energy is responsible for roughly the same proportion of global CO_2 emissions [6]. The use of traditional carbon-based sources of energy (oil, gas and coal) has caused devastating damage to the environment and to human health. Climate change, which is generally regarded as a result of methane and CO_2 emissions, stratospheric ozone and acid precipitations, is the most fundamental environmental problem worldwide. Consequently, many countries (including the GCC) have begun to prioritize this topic in their future energy planning. In 2001 an economic agreement was reached between the GCC countries aimed at addressing the negative impact of using fossil fuels on the environment. The commitment was extended internationally by the signing of the Kyoto Protocol treaty under the United Nations Framework Convention on Climate Change, by the GCC leaders (UNFCCC, 2004).

Figure 1.1: The Arabian Peninsula [7]

Renewable energy (RE), comprising solar, wind, hydropower and other sources, is the only sustainable alternative to fossil fuels. RE is relatively clean, widely available and unlimited. According to [8], renewable energy sources (RES) currently supply 15-20% of world energy demand. Renewable energy technology (RET) specifically for the generation of electricity has made sizable technical advances and is now readily available. As RET matures, the cost gap between it and traditional energy sources is closing, enabling RES to become cost competitive with traditional energy (TRE) in addition to its environmental advantages.

1.2 Types of Renewable Energy Sources

- Solar: sunlight that can directly heat and light homes and commercial buildings. Two kinds of solar architecture technologies exist: passive solar design and active solar air and water heating thermal power systems using photovoltaic power generation.
- Ultra Efficient Solar Cells: regular solar panels usually convert less than 20% of that energy into electricity, but this new technique doubles the power efficiency of solar devices by breaking sunlight into six to eight component wavelengths, each of which generates a different colour of light. Each colour is then distributed to a specific cell with a semiconductor that can absorb it.
- Wind: the heating and cooling of the Earth by the Sun produces wind, which can be transformed into energy. The wind technology can be land-based and/or offshore, using wind turbines.
- Hydropower: energy generated from moving (falling or running) water. Hydropower plants use a dam on a river or pumped storage.
- Biomass: energy obtained from organic matter (ultimately from photosynthesis) through burning and digestion of wastes from municipal animals, humans, industrial and agricultural sources. Biomass can be incinerated in waste-to-energy plants to heat water, producing steam that drives turbines as in traditional power plants.
- Geothermal: energy generated from hot dry rocks and high enthalpy sources.
- Ocean Energy: shoreline and large off-shore wave power systems.
- Hydrogen: hydrogen fuel systems using RES are a less attractive source of energy because they require combination with other elements.

1.3 Renewable Energy and its Barriers

RE can be generated from ecological resources that are naturally replenished, including biomass, wind, solar, hydro and geothermal. RES are therefore free, clean, and basically harmless to human health as well as to the environment, thus many countries try to use this source of energy as a substitute for traditional fossil fuels. The potential of those sources is enormous as in principle they could furnish the entire world's energy demand. RES currently supply somewhere between 15-20% of the world's total energy demand [9]. In brief, as stated by [10], RE is the general term used to describe a heterogeneous group of energy sources, primarily bio energy, wind power, hydro power, solar power and solar heating. Unfortunately, just like any new technology, RET faces many challenges in the GCC countries. Government policies, public awareness, knowledge, lack of political support, and cheap oil and gas prices are some of the structural barriers to the use of RET. Additionally, dust, heat and humidity comprise major environmental hindrances to the efficiency of such technology to generate energy.

1.4 The Research Aim and Objectives

The primary purpose of this research is to examine the feasibility of adopting renewable energy to be used locally in the GCC countries, to explore related barriers, and to assess economic value. The GCC was chosen because its constituent countries have similar socio-cultural backgrounds, governmental and economic policies, while being the historical foundation of fossil fuel supplies for the developed world in the last century. In this work the author conducted an in-depth case study of Kuwait.

The objectives of this research are to:

1- Display a comprehensive picture of knowledge through the review of the literature regarding RE application and related barriers in the developed and developing countries. Moreover, to evaluate the feasibility of adopting RES locally in the GCC countries, and the barriers that hinders its adoption and implementation (as discussed in chapters 2 and 3).
2- Investigate Kuwaiti public, official and academic attitudes and knowledge of renewable energy and its barriers, through the use of questionnaire, to establish a baseline of Kuwaiti attitudes towards and knowledge of renewable energy for the purpose of evaluation, and to provide results and recommendations to Kuwaiti government (chapter 5).
3- Discover whether the adoption of RES (solar and wind) adds any economic and environmental benefits to Kuwait by conducting a cost-benefit analysis (chapter 6).
4- Design and construct a model that can be used as a road map for sustainable and effective RE implementations based on RE feasibility in the GCC states and its

existing berries, and whether the Al-Shagaya RES project in Kuwait adds any substantive economic and environmental benefits for Kuwait (Figure 7.1).

5- Address the conclusions, recommendations for decision makers and recommendations for future research of RES.

1.5 The Methodology Model

In this study, the methodology was constructed through the use of the model shown in Figure 1.2, which is concerned with the investigation of a prospective future in RE for the GCC countries. The methodology of this research contains four components: a critical review of previous literature, a questionnaire, a cost analysis and the renewable energy road map model. The aforementioned methodology model contains two primary arguments: whether RE is feasible in the GCC states, and what barriers exist to the implementation of RE technologies (if any). The second argument regards any beneficial effects or positive externalities (whether they are economic and/or environmental) that may be gained by the state of Kuwait (such as in the case of Al-Shagaya).

To test the first argument, the author administered a questionnaire and utilized knowledge gathered from the literature review on two types of barriers: administrative barriers (such as clear policies, public awareness, cost, and know-how) and environmental barriers (like dust, heat and humidity), coming up with specific recommendations on how to mediate them. The author testing of the second argument was achieved using a cost analysis of the cost of electricity generated from the Kuwaiti Ministry of Electricity and Water (MEW) compared to the cost of electricity generated by the Al-Shagaya Project until 2030. In addition, toxin levels generated by the burning of traditional fossil fuels to generate electricity will also be compared to the reduced toxin emissions from the Al-Shagaya Project within the same timeframe. This is used as a basis for multiple recommendations and the road map model for decision makers, which concludes in this research.

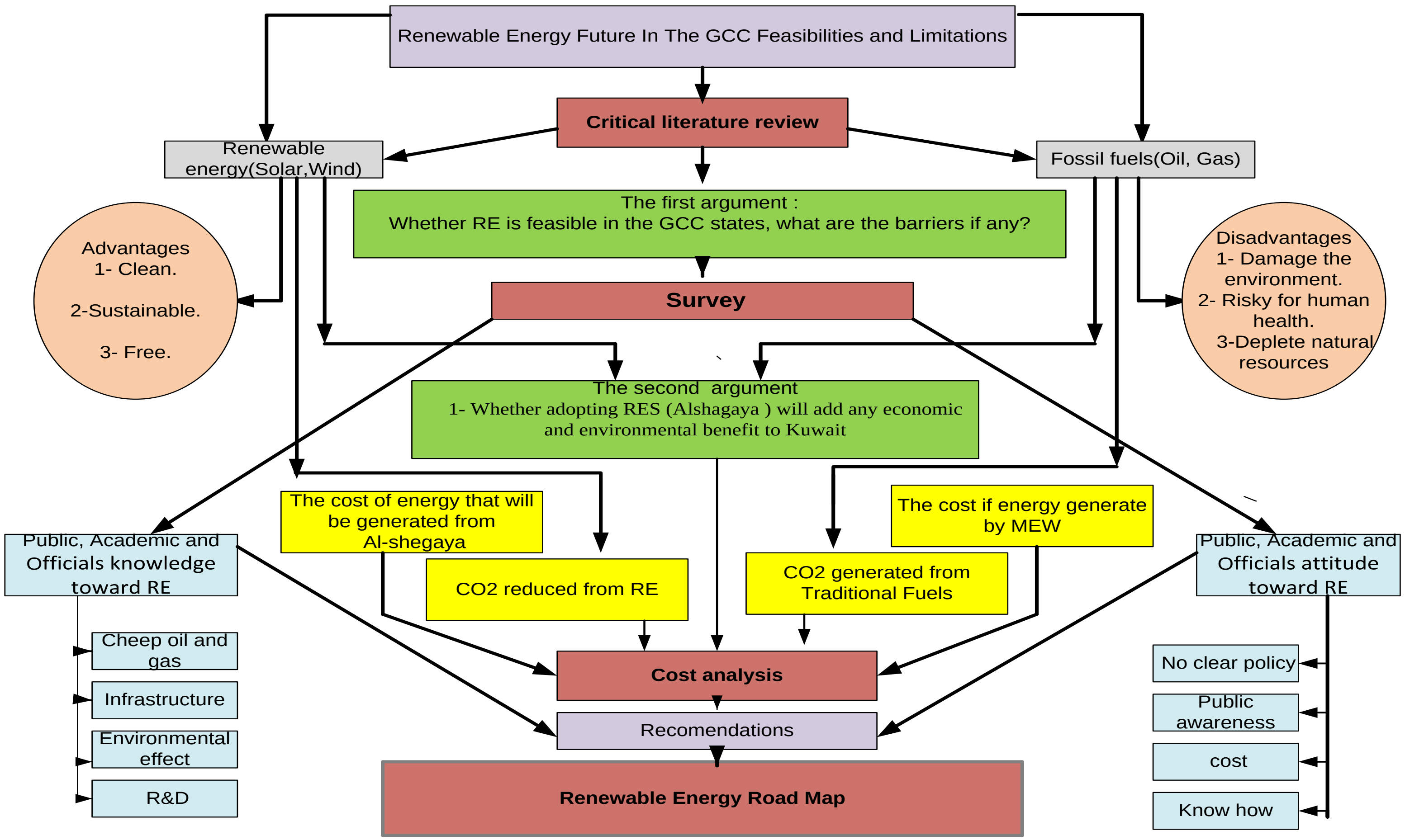

Figure 1.2: Renewable energy in the GCC

1.6 Organization of the Thesis

A critical literature review is presented in chapters 2 and 3. The literature mainly highlights the negative impacts of using fossil fuels on the environment as well as human health and discusses in depth the application of renewable energies. Chapter 2 investigates RE applications and related barriers in the developed and developing countries (internationally). Chapter 3 discusses RE possibilities, applications and related administrative and environmental barriers in the GCC states, the electricity generation in Kuwait and the current RE applications and finally focuses on variables of attitude and knowledge in relation to RE.

A questionnaire was designed by the author to investigate the attitudes and knowledge of the Kuwait public, academics and officials toward RE. The main purpose of this questionnaire is to examine factors, attitudes, and knowledge of how these target populations regard RE and their actions concerning it. Details of the questionnaire methodology are given in Chapter 4.

In order to answer the second question in the methodology of whether adopting RES will add any economic and environmental benefit to Kuwait, a cost analysis was carried out in chapter 6 to predict the cost of traditional energy generated by the MEW compared to the cost of RE generated from the new Al-Shagaya Project in Kuwait until 2030. Moreover, an estimation of CO_2 emissions and reductions for the same period is calculated.

1.7 Contribution to Knowledge

The contributions of this research to knowledge are outlined below.

1. The critical literature review presented in this thesis investigates in depth the negative impact of the uses of fossil fuels on the environment and human health, and addresses the application of RES in the developed and developing countries and their related barriers. On the other hand, the literature discusses the possibilities, barriers and applications to RES adoption in the GCC states.
2. A set of questionnaires were designed and distributed to the three target groups (public, officials and academics), to measure their attitudes, awareness and knowledge of RE and its related barriers. The data obtained

was analysed using SPSS (Statistical Package for the Social Sciences program).

3. A crucial cost and environmental analysis is presented between the cost of traditional energy sources predicted to be generated by the MEW using fossil fuels, compared to the cost of the energy that will generated from the Al-Shagaya RE project until 2030. Based on the above analysis, an estimation of how much CO_2 will be generated from traditional energy, and how it will be reduced as a result of using RES, is given for the same period.
4. A model is designed to be a road map for policy makers.

1.8 List of Publications

Alloughani, M., & Balachandran, W. (2011). Can The GCC States Become Ideal Examples for Environmental Sustainability by Using Renewable Energy Locally? *Journal of Culture and Development in the Arab Republic of Egypt*, page 49.

Alloughani, M., Balachandran, W., & Manivannan, N. (2015). Can Kuwait Gain Economic Benefits by Adopting Renewable Energy? Submitted to *IET Renewable Power Generation*.

CHAPTER 2: RENEWABLE ENERGY IN THE DEVELOPING AND DEVELOPED WORLD

This chapter critically reviews literature pertaining to renewable energy in the developed and developing countries. In particular, the applications of RE, the barriers within the RE sector and the solutions found to the barriers are extensively reviewed. Negative impacts of traditional energy generation by fossil fuels are also reviewed in this chapter.

2.1 Renewable Energy in Developed and Developing Countries

The growth of the world's population and energy-consumption, particularly through the on-going industrialization of developing countries like China, India and Brazil, will increase and extend heavy dependence on fossil fuels for many years to come. Although global consumption of fossil fuels is in gradual decline (oil by 1.7%, natural gas by 2.1% and coal by 10.4% in 2009), those conventional energy resources are still the core of power generation infrastructures throughout the world [11]. Additionally, since the discovery of fossil fuels in the GCC countries during the 20th century, the economic growth, infrastructural growth, and social development of those countries has hinged on fossil fuels, affecting all aspects of local life, most importantly generating electricity and desalinating water for human needs. However, the carefree consumption of relatively cheap fossil fuels contributes to the depletion of natural resources, damaging the environment and adding to global climate change.

All stakeholders in fossil fuel industries – including consumers throughout the globe, as well as companies and producers involved – have an ethical obligation to take action and help alleviate the damages caused by such consumption, as observed by the BP Chief Executive John Brown: "If we are all to take responsibility for the future of our planet, then it falls to us to begin to take precautionary action now" [12]. There is an imperative need to discover alternatives to conventional resources of power generation for logistical, environmental and geo-political reasons [13]. Global efforts are growing to develop clean energy; however, all RES combined account for only approximately 18% of global energy utilization [11].

2.2 The Negative Impact of Fossil Fuels on the Environment

Today most of our energy comes from burning fossil fuels, which have driven global economic development since the increasing industrialization of the 18th century. However, those traditional sources of energy are limited and can severely harm the environment. According to [14], the burning of fossil fuels was responsible for 79% of US greenhouse gas (GHG) emissions in 2010. Moreover, atmospheric CO_2 has increased by nearly 30% and the average global temperature has risen by 0.3^{o} (0.6°C) in recent decades [15]. This energy consumption has a direct impact on the environment due to air pollutants and GHG emissions, leading to the development of many studies displaying their harmful effects. [16] explained the effects of climate change caused by the burning of fossil fuels, which releases carbon dioxide and other greenhouse gases into the atmosphere, causing the Earth to warm at a rapid pace. [17] cited global climate change, stratospheric ozone and acid precipitations as the most crucial environmental problems, all of which are attributed to the exploration, development and production of traditional energy sources, such as oil, gas and coal. These processes are categorized as the most hazardous to humans and the environment [18].

Nevertheless, the evolution of the global economy over the past two centuries has presented an insatiable need for increased fossil fuel production and consumption. As the oil beds and raw materials deteriorate due to mass consumption, negative effects are manifested in the environment, challenging its ability to sustain life. Aside from the macro-level, global process of climate change, oil refineries in themselves directly generate an abundance of toxic wastes, which deplete the local environment and destroy its natural condition. Carbon emissions (which with methane from cattle ranching are the main human cause of global warming) arise due to burning fossil fuels for the purposes of manufacturing, transportation and local use [19]. The International Energy Agency (IEA) issued a pie chart showing the global greenhouse gas emissions that are released into the air from multiple sources (Figure 2.1).

According to [20] and the UN Intergovernmental Panel on Climate Change (UNIPCC) Report, ‘global climate change is an observable fact beyond all doubt [21]. Within the past decade the Earth has seen the warmest surface temperature since 1850' [22]. The report attributes the many natural disturbances in the world such as melting ice caps, and the increasing number of severe storms to the temperature increases. Furthermore, it is anticipated that there will be a rise from 75 to 200 million people that are at risk of flooding by coastal storm surges in case of a mid-range climate change, in which a rise in the sea level of 40 cm is predicted by the 2080s.

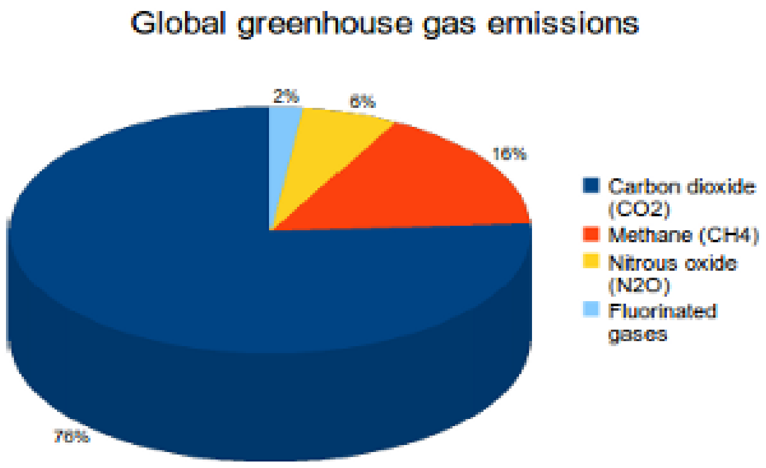

Figure 2.1: Global greenhouse gas emissions

Source: International Energy Agency 2012 (IEA) [19]

2.3 The Negative Impact of Fossil Fuels on Human Health

Health hazards are another significantly negative effect, and many researchers [23-27] investigated the detrimental effect of climate change on human health. [28] concluded that changes in the broad-scale climate system would definitely affect human mortality and morbidity due to extreme heat. To evaluate air pollution as it relates to health in developing countries, [29] found that 40-60% of acute respiratory infections are due to environmental problems. They concluded that the current consumption of fossil fuels in developing countries is half that of the developed countries, but it was projected to increase from 1999 by 120% by the year 2020; more than 6.34 million people will die per year in developing countries due to emissions concentrations of particulate air pollutions. As reported by [30], carbon monoxide (CO) is the product of incomplete combustion of any fuel. It is an extremely toxic gas and the source constituent of photochemical smoke. The effects of CO exposure on human health are summarized by the Department of Energy in Pennsylvania State University in the table below (Table 2.1).

Table 2.1: Health effects associated with human exposure to carbon monoxide [30]

CO concentration (parts per million)	*Duration of exposure (hours)*	*Effect*
100	10	Headache
300	10	Nausea
600	10	Death
1000	1	Unconsciousness
1000	4	Death

[31] emphasized that climate change manifested as temperature extremes and rainfall is the product of the "accumulation of greenhouse gases in the atmosphere arising from the combustion of fossil fuels". Many studies [24, 31-33] assert that climate change in the form of heat waves, floods, and drought can lead to respiratory diseases, sunburn and melanoma (Table 2.2). They add that it is primarily attributed to causing heat stroke, drowning and gastrointestinal diseases, and the ecological alterations stimulated by climate change can increase rates of malnutrition, allergies and exposure to many vector-borne diseases (e.g. dengue, malaria, Lyme disease). According to [21], the world needs to reduce greenhouse gas emissions by 60-70% in order to maintain the atmosphere and limit the inevitable harmful effects to ecological and other biophysical systems.

Several studies agree with [24], holding that more daily deaths and diseases are accruing due to the increased number of hot days, e.g. [34][35], whereas studies such as [36] and [28] announced that floods cause more injuries, infectious diseases, mental health disorders and deaths. [26] studied how climatic trends affect health as several main climatic-environmental manifestations of climate change (Figure 2.2). Many countries and international organizations have begun developing strategies to help mitigate climate change and its harmful effects on the environment and human, animal, and plant health, notably the EU Commission [37].

Table 2.2: Summary of public health impacts of climate change [31]

Health outcome	*Public health*	*Surveillance*
Mortality and morbidity due to heat waves	Public-health education	Enhance health surveillance of routine data for early detection of heat wave effects (e.g. monitoring from funeral homes, calls to NHS Direct)
	Heat health warning systems	
	Emergency preparedness	
Floods	Public-health education (e.g. boil water notices)	Surveillance for flood effects, with long-term follow-up
	Emergency preparedness	Coordinated national surveillance for flood deaths, injuries, and illnesses
	Check list for post-flood activities	
Air quality	Warnings for high pollution days	Daily air pollution measurements
Vector diseases	Public education, especially to avoid contact with ticks	Monitoring of vectors and reservoir host
		Integrated surveillance for human and animal diseases
Food disease	Maintenance and strengthening of food hygiene measures	Integrated surveillance for human and animal diseases
Water diseases	Risk assessment for extreme rainfall events	Increased microbiological monitoring of public water supplies and private wells, and enhanced surveillance during and following heavy rainfall events
	Risk assessment of health effects of algal blooms	

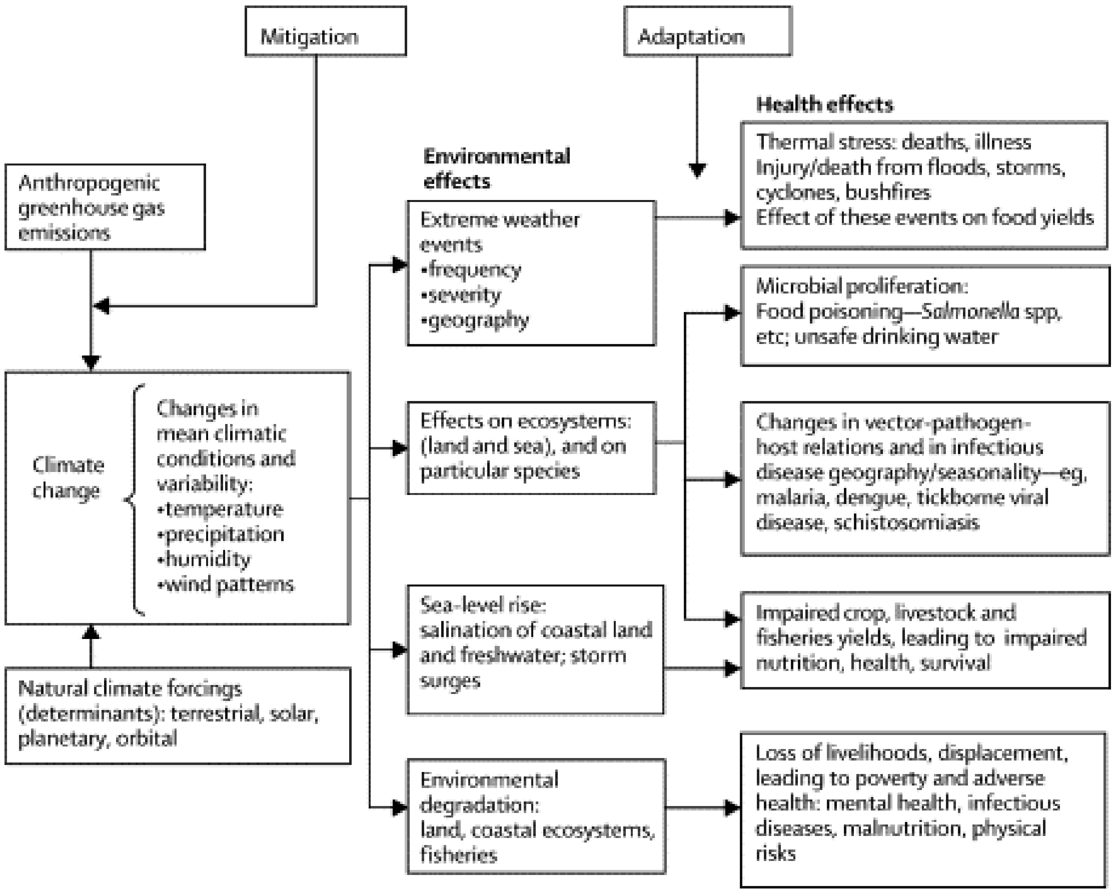

Figure 2.2: Climate change effects on population health [26]

Because immature immune systems are more likely to be affected by the environment changes, [24] studied the impact of climate change on children's' health, finding the following devastating diseases were linked to climate change, and making the complementary recommendations:

1. Asthma: parents should be advised to learn about local air quality and to appropriately regulate their child's outdoor activities.

2. Sunburn: protective wear and the use of sunblock are encouraged. Midday activities outdoors should be discouraged.

3. Heat stroke: basic knowledge on how to treat acute heat stroke is necessary. Parents must have basic knowledge of hydration and appropriate play outdoors.

4. Diarrhoea: advice should be provided about the management of diarrhoea at home. Dehydration and other symptoms should prompt admission to a hospital.

5. Allergies: emphasis on the recognition of different symptoms, and families should be educated about preventive actions.

6. Dengue, malaria, encephalitis, and Lyme disease: be aware of the symptoms, and management of these illnesses. Parents should be encouraged to use screens, drain stagnant water, and dress their children in clothing that can offer protection from mosquitoes.

7. Emergent diseases: the encouragement of active prevention when it comes to health and safety.

2.4 The Emergence of Renewable Energy Internationally

Renewable energy can be generated from ecological resources that are naturally replenished, including biomass, wind, solar, hydropower and geothermal. Due to the fact that RES are free at source, the potential of those sources is vast as they could in principle meet the world's energy demands. According to [38] and the IEA (1997) [39], RES would provide approximately 15-20% of total world energy demand by

2020 based on a projected approximately 8-9% of yearly progress in the commercial utilization of energy from 'new' RES by 2010; the World Energy Council (2010) [40] typical scenario growth of RES to meet 18-21% of world needs by 2020, and ecologically determined scenario growth from 18-30% of world needs by 2020. The UN anticipated that up to 30% of world needs would be met by RES by 2025, and 45% by 2050. The IEA provided several guidelines to promote the use of RES [39]:

1. Developers, consumers, planners and financiers need to gain confidence in RE.

2. Governments should give urgent attention to the importance of RE to meet international energy development and environmental objectives.

3. Energy prices have to reflect the environmental costs to society of producing and delivering energy to consumers.

4. Initial markets need to attract private investment in RE.

5. Raising public awareness of RE and its environmental implications.

6. Investment in empirical research to bring down the cost of renewable energy technologies.

7. Energy companies must be more committed to RE.

8. International collaboration on the development of RE technologies between OECD (The Organization for Economic Co-operation and Development) countries such as Japan, USA, New Zealand, Mexico, and Italy.

The EU increased their share of RE in the supply of electricity from approximately 14% to 22% over thirteen years to 2006 [41]. Three existing RETs and geothermal energy provide more than 20% of electricity in the countries of the OECD: 1) hydro power, which supplies 100% of local electricity in Norway and 60% in Canada; 2) biomass in the form of wood fuel and digester liquors, which supplies up to 90% of total energy in Nepal and Malawi; and 3) geothermal energy, which provides more than 20% of all RE in the OECD [41].

Many researchers [41-44] claimed that the emergence of the RE market is motivated by three factors: a) rising fossil fuel resources prices; b) concern about energy supply security; and c) climate change due to pollution. [45] outlined German policies on two RETs: wind turbines and solar cells. They claim that because of the energy crises of the 1970s, and strong environmental concern over acid rain in the 1980s, the German government supported the development of RES such as wind and solar by investing in research, supporting farmers and technicians, and encouraging customers and investors. Parallel action was taken by the German government in establishing the form of the Feed-in Law for solar power, and 3000 member firms of the Equipment and Machinery Producers are investing in RE projects. The Feed-in Law issued by the German Federal Ministry for the Environment in 2000 states that the government implicitly commits to bearing external costs, as the traditional sources still benefit from large government subsidies which help maintain low prices and thus prevent the development of RE. They come to the conclusion that German public opinion appears to favour climate policy control and investment in RE projects, and that all costs such as subsidies and external costs are held to favour Germany in financial and employment terms.

The UK innovation systems for five RETs (wind, marine, solar PV, biomass and hydrogen) were analysed by [46], who found that RE from onshore and offshore winds displays market growth and cost reductions, but the energy market regulations and renewable support policies could be challenging. RE faces a gap between R&D and implementation; and solar PV is a relatively small and costly program. They found that the UK RETs innovation system failures:

> ‘appear to be happening at two stages for several technologies in the UK: at the transition between the demonstration stage and the pre-commercialization stage, and between the pre-commercialization and supported commercialization stage’ [46].

Also, because of the fact that these innovations are still in their early stages and cannot attract investment, they are high-risk and high-cost technologies, and lack competitive advantages and support for R&D. Finally, the study calls for a range of policies and regulations to ensure framework stabilization while technologies are moving toward commercialization.

[47] conducted a two-year study to investigate the main barriers to RETs in Maharashtra State, India. India has sufficient energy sources spread all over the country, such as synthetic fuels, solar, biomass, and hydro energy, but the study shows that there are six existing barriers: (1) lack of awareness and deficit of information regarding RETs for consumers and industries; (2) financial and economic constraints represented in high initial costs and high on-going operating costs; (3) technical risks during the technical performance; (4) market barriers and failures caused by the cost and lack of competitive advantages; and (5) institutional and regulatory barriers due to lack of a coherent national policy for RE at end-use level.

The questionnaire's results display a majority of participants agreeing that the Indian government must develop a policy for RE that will regulate cost and savings in order to enable investment in such energy. It was found that difficulty in getting equipment and spare parts, lack of skilled personnel to operate equipment and facilities, official regulation, land acquisition, the fluctuation of wind and solar energy availability and infrastructural limitations undermined the adoption of RES in India [48].

In terms of assessing RES, [49] investigated RES on four components: RE performance, supply chain, barriers and strategies for development. They found that although RES are enormous, they are unpredictable and uncontrollable due to changing weather conditions, and supply chains are affected by physical, information and financial flows. Industries' awareness of green manufacturing process, constructing logistics, and products as associated to supply chain management performance as well as technology are also potential challenges.

The RE supply chain performance relies on its conversion productivity, which contains distribution, storage, efficiency and secondary applications efficiencies. To help improve the RE supply chain, governments should utilize scientific research, especially concerning advanced storage technology and distribution network and for more effective innovation and distribution networks.

2.5 Wind and Solar Energy Generation in Developed and Developing Countries

As long as the Sun shines, there must be wind on the Earth, because it is the uneven heating of the Earth (particularly the sea) by the Sun that creates wind. Using hundreds of wind turbines captures wind energy in wind farms, what researchers identify as ‘the most cost-efficient form’ of RES [50]. The UK is a leading country in surveying public opinion on wind energy (e.g. organizations such as the British Wind Energy Association, Scottish Renewable Forum, British Broadcasting Corporation, Countryside Council for Wales, Department of Trade and Industry, and the University of Wales Environmental and Countryside Planning Unit). The majority of those surveyed favoured wind development energy projects [51]. An NOP World (2005) [52] survey of 1,000 adults on behalf of the British Wind Energy Association indicated that 80% of participants agreed that wind farms are necessary, and 62% did not mind the appearance of wind farms; however, 81% accepted the principle of wind farms, but would not want one near their local area.

Wind power consumes no fuel and is waste-free [53]. Wind-energy turbines are not typically installed in urban areas as buildings can interfere with wind. They are usually built on land that has already been affected by land clearing. A study issued by the New South Wales Government (2010) indicates that when the Sun passes behind the turbines, residents located around it might complain of ‘shadow flicker’ on residences caused by rotating turbine blades. [54] This can certainly be avoided by locating the wind farm to avoid undesirable shadow flicker, or by turning the turbine off when the Sun is at the angle that causes flicker. If a turbine is poorly located and adjacent to many homes the shadow flicker can cause considerable annoyance. Therefore, several studies have been conducted to understand the attitudes of residents regarding wind power; these studies provide governments with better understanding of the impact of this kind of green energy. [55] analysed the perceptions of wind power among 520 Swedish residential electricity consumers. The results suggested that the average Swedish house owner is generally favourable of wind power, although noise levels, location, height, and the grouping of windmills are their major concerns.

According to [56], Canadians believe that wind-generated electricity must be a priority in Canada by 79%; similarly, 82% of Danes show favourable attitudes toward utilizing wind energy.

At the end of 2009 the world overall installed capacity of wind energy was reported by the World Wind Energy Association (WWEA) [57] as follows: worldwide capacity reached 159213 MW; the year 2001 reported the highest wind power growth rate of 31,7%; the wind capacity development double every three years; toward the end of 2009 worldwide wind turbines were generating 340 TWh per annum, equivalent to the sum of electrical mandate of Italy, and equivalent to 2% of worldwide electricity consumption; in 2009 the wind sector had a revenue of €50bn; and employs 550,000 people worldwide. In the year 2012, the wind industry was anticipated to offer a million jobs; China has the biggest market in the wind industry and turbines with 13,800 MW generated that was doubled consistently for the fourth year in a row; the US maintains its top position in installed capacity with around 26,000 MW of wind capacity installed, followed by China. The largest portion of new installations is accounted for by Asia (40.4%), North America followed (28.4%), and Europe in third place (27.3%); Latin America (Brazil and Mexico) disclosed doubled installations; and because of hastened development and improvement of policies, WWEA predicted a growth in global capacity of 1,900,000 MW by the year 2020.

Hawaii has the potential to generate all natural energies currently used, from solar radiation, wind power, sea power, to biomass [58]. Hawaiian officials operate for the successful use of solar and wind as sources of energy involving the so called ‘Delphi method’, which gathers the cumulative knowledge of specialists in environmental, technology, engineering, and economics fields and local experts to evaluate impacts. As a consequence, Hawaii leads in utilizing solar energy in the form of agricultural drying, water heating, and wind power. In recent years, Hawaii generated 326 million kWh from wind power, according to the US Energy Information Administration (EIA) in 2011 [59].

Since 1980, Greece’s industrial solar thermal applications have had serious quality problems in terms of maintenance and financial difficulties due to increasing liquid fuels prices. Today Greece owns eight successful solar thermal system projects [60].

After thirty years Greece uses local solar hot water systems, [61] studied their environmental benefits and perceptions. They found that in 2007 the conserved energy used ranges about 0.1% of the local sector energy, causing an abundance of CO_2 emissions, which was 1.67 Mt in 2000, more than 76%, the goals of the Greek Program of 'Climatic Change', which showed savings of 0.95 Mt CO_2 for 2000.

Desiccant cooling system is widely used in Hong Kong for hot, wet weather; [62] analysed the energy and economic performance of this application using comparison method with the conventional air-conditioning system. They found significant energy saving potentials of incorporating open cycle solar desiccant dehumidification air-conditioning system in Hong Kong weather conditions. This is because of higher convective and or graphically-induced precipitation, which results from a higher supply of chilled weather temperature, along with the benefit of energy savings and a reasonable payback period. They concluded that the economic possibility of the open cycle solar desiccant air-conditioning system can be further enhanced by changing the auxiliary electric with a gas boiler.

Developing countries such as China hope that the RE photovoltaic (PV) and wind can offer economic and environmental sustainability, especially for rural households. A case study comparatively analysing energy output and system performance of PV, wind turbine and wind hybrid RE generation for 41 homes in Inner Mongolia (China) considered the availability of RES, system specifications and costs, household requirements, policy and finance [63]. The study found that, as in developed countries, using RETs as a source of electricity costs more than diesel or gasoline. Therefore, it suggests that the Chinese government needs to establish policies, goals and institutional policies and strategies for rural RE development. Furthermore, the study urges the government to establish an RE market and fund to help support demonstration projects and loan funds to overcome obstacles to the purchase of RE systems in rural areas, but it discourages subsidies to local RE manufacturers.

China is "the largest developing country in the world" [64], with huge economic development, environmental pollution, energy shortages and climate change effects [65]. China is facing severe environmental crisis caused by consuming fuel burning for industrial, residential and transportation; researchers also consider China the second largest country in energy consumption, with about 1500 million tons of coal, China's primary energy source for decades to come [66]. [67] discussed the solar energy applications in China's buildings. China has invested $1.25bn (US) in developing solar photovoltaic applications for the building industry, involving solar water heaters, solar refrigeration, solar heating buildings, air conditioners and photovoltaic systems. Recently, China became the biggest solar water heater producer, with more than 10 million m^2. However, China is facing major obstacles in policy disadvantages in the building sector, lack of solar energy technology, and absence of national economic incentive mechanisms.

The demand for primary energy in developing countries such as Pakistan has increased considerably over the last decades because, as with most developing countries, Pakistan faces a serious energy shortage. However, Pakistan has strong potential for solar power generation [68] due to its geographical location and climate, which facilitates utilizing solar thermal and photovoltaic systems [69]. The results of the aforementioned studies showed enormous success, with average of 10 hours solar radiation intensity a day ranging from 1500 W/m^2/day to 2750 W/m^2/day in the studied regions of Pakistan throughout the year. In an area of 100 m^2, 45 MW to 83 MW power per month may be generated in the abovementioned regions. However, both studies show that the Pakistani government needs to work on an effective plan for increasing energy efficiency in terms of policy and technologies.

Industrial applications of solar energy in Jordan was assessed in its present state and forecast for the future [70]. The results show that Jordan spends around JD 736 million on primary energy from neighbouring countries, with a 2.1% share of solar energy, which saves around 16 million JDs. They suggest that the Jordanian government procedures on solar energy focused on direct funding of research, the development of an institutional framework to ease the use of solar energy, and measures to improve solar energy technologies and performance. [71] encouraged the use of industrial solar energy in Jordan, which has similar conditions to Pakistan. He found that solar applications isn't well established and urged the Jordanian government to establish a research centre and build industrial solar energy.

2.6 Barriers to RE Development

Many researchers, [38], [72][73] studied the barriers to RE to help overcome them and improve their implementation and economics benefits. They agree that the potential of RE has not been fully realized due to several barriers. The Union of Concerned Scientists (2010) [74] classified these barriers into four categories:

- Commercialization barriers as the new technologies compete with traditional and old ones.
- Subsidies that displays price biases and baseless tax when comparing RE and other energy sources.
- The market is not reflecting the social cost.
- Market obstacles such as insufficient information, 'split incentives' between landlords and residents.

RE cost is a major concern to most governments [75]-[76]. As stated by [49], fuel costs influence the cost of electric power and have affected the marketing price and consumption of RE. They add that many countries employed legislations and plans to overcome the gap between these prices by employing certification or tax refund. On the other hand, studies agree that some RES can be expensive but attractive in the context of high fossil fuel prices [49], [76].

China increased its RE use and experienced barriers in financing and finding the right technologies for its development of RE projects. However China known for leading carbon dioxide emitters in the world, [77] discussed the use of Clean Development Mechanism (CDM) to advance RE deployment in China. The CDM allows a company that chooses not to reduce its own emissions to purchase credits from the CDM project to offset them, and the CDM project thus supports the development of the RE by proxy.

The actions, policies, targets and barriers of developing RE in Queensland (Australia) was investigated by [78]**.** The Australian government has some of the highest RE targets in the world, aiming to meet 20% of all electricity needs with RES by 2020. However, serious barriers to this include:

1. Finance and economics: such as high project cost, inadequate financial motivations; plentiful fuel resources and cheap coal-fired power;
2. Infrastructure: lacking network capacity;
3. Technical and Education: lack of technology, expert personnel, and lack of education programs and awareness;
4. Legislation and policy: state regulation obstacles and land use.

Similar to Australia, Greece faces the same RE barriers presented by [79], such as technological barriers and the lack of information; inadequate national strategy to evaluate the impacts of RE projects; absence of financial benefits for RE investments; lack of state legislation for RE installation development; and license complexity. RE applications barriers in Turkey as deliberated by [80] can be summarized as high capital costs related to building infrastructure to promote clean energy source; and the prohibitive cost of RES, which inhibits their penetration of electricity markets.

2.7 The Environmental Impact on Solar Panels

Like any new technology, RET, especially solar and wind technology, faces many environmental challenges such as dust and humidity. ‘Dust’ is generally defined as a minute solid particle of less than 500 µm diameter [81]. Various sources, such as dust lifted up by the wind, pedestrians, vehicular movement, volcanic eruptions and pollution attribute to the accumulation of these particles in the atmosphere. The accumulation of dust on any PV panel is affected by human activities and weather conditions. The properties of dust play a part in solar panel combinations; chemical, biological and electrostatic properties; and size, shape and weight. The dust particles can be categorized into three groups: (1) particles with a diameter of over 10 µm; (2) particles with a diameter of 2.5 to 10 µm; and (3) particles with a diameter smaller than 2.5 µm [82].

[83] examined the impact of dust accumulations on solar panels. They conducted a three-month performance test on collectors having 30^o tilt angle located in an industrial district near a power plant, 92 m away from a four-track railroad, in

Boston (US). The results of the test indicated that the dirt's effect on the collector's net performance very marginal (4.7%), while the calculations indicated a 2.7% maximum reduction in glass transmittance. They accredited these values to the collector's self-cleaning action, incorporated due to precipitation, mainly, rainfall and snow [83].

[84] tested the effects of dust on a solar PV system in Roorkee (India), comparing glass plates and plastic films. Given that horizontal glass collects more dust than vertical, the test results indicate that the after a month's exposure transmittance values for horizontal and vertical glass plate were 30% and 88% respectively, with a reduction in transmittance of only 8% for a 45^o tilted glass after a month. On the other hand, it was concluded that dust accumulation is more likely to occur on plastic films, because of their higher electrostatic tendency to draw dust. Hence, daily cleaning for both glass- and plastic-film based collector plates is necessary.

The effect of dust accumulation on transmittance with low density polyethylene glazing and plastic material was also studied by [85] in tropical climate conditions in Bangkok, Thailand. An 11% reduction in transmittance was estimated for 5 g/m^2 depositions over a month (under natural conditions), for a plastic cover in tropical humid conditions; maximum dust accumulations were 3.7 g/m^2 for a month.

[86] also studied the effect of dust accumulations on glass transmittance in a subtropical climate in Minia (central Egypt). In a one-year experiment the researcher studied nine square glass plates with 3 mm thickness, and an exposed surface area of 0.09 m^2. One plate was kept clean (as a reference plate), while the others were placed on flat wooden frames facing south having varying inclinations (0^o, 10^o, 20^o, 30^o, 40^o, 50^o, 60^o and 90^o) to examine the extent of dust accumulations over 30 days. The findings indicated that for tilt angle less than 30^o dust accumulations were largely climate-specific. A weekly cleaning cycle for places exposed to moderate dust level and an immediate cleaning subsequent to dust/sandstorms was recommended.

In China, [87] studied the effect of dust accumulation on a variety of types of solar PV modules and the corresponding efficiency degradations. The experiment was conducted in the laboratory with a Sun simulator and a test chamber. The degradation of PV module efficiency caused by dust deposition under various conditions was investigated. The results showed that the accumulation of dust has a significant impact on PV module output.

Extra-terrestrially, dust is a major environmental factor on the surface as well as in the atmosphere of Mars [88]. Mars' atmosphere contains a considerable amount of suspended dust that settles out of the atmosphere and deposits onto the surfaces of solar arrays, resulting in degradation of performance. An attempt to quantify the anticipated dust coverage and performance degradation was made by [89] with regard to Martian data (i.e. from the planet Mars). It was found that, similar to desert conditions, wind-swept dust from the surface and it later deposited due to atmospheric suspension (this process is known as salutation).

2.8 Summary

A review of the international literature reveals that the continued use of fossil fuels has unavoidable and devastating impacts on human communities and the environment, whether through the destruction of our ability to sustain life or the damage to human health and quality of life. Alternative RES exist and numerous studies have shown the methods and challenges to implementing these resources. RE applications and implementation requires political will as well as knowledge at the national, municipal and community levels of developing and implementing RE.

CHAPTER 3: RENEWABLE ENERGY IN THE ARABIAN GULF COUNTRIES

This chapter explores literature on RE in the GCC countries, which is the main focus of this thesis. The current state of RE applications (both commercial and research) and the barriers that hinder the efficient use of RE technology in the GCC countries is extensively reviewed. This chapter also reviews electricity generation by traditional means in Kuwait, which establishes the major case study of this thesis. Moreover, literature is reviewed concerning attitudes and knowledge in the GCC with regard to renewable energy.

3.1 Renewable Energy in the GCC

The concept of alternative energy in the GCC can be traced to October 1973, when Saudi Arabia, a key member of OPEC, declared an oil embargo due to the US decision to support and supply the Israeli military. Although this crisis passed with minimal effect, this was a precedent for developing countries searching for other ‘new’ RES to secure the energy supplies necessary for their continued economic development.

3.2 GCC Countries’ Environmental Policies and the Kyoto Protocol

[90] observed that the GCC countries face serious physical challenges, such as desertification, biodiversity loss, air pollution, the pollution of coastal and marine areas, and water scarcity and quality deterioration. The UNIPCC’s report claims that climate change is the scientific cause of the rising average global temperature, and if this rise exceeds 2-3^{o}C it will cause the world to face destructive outcomes such as a persistent rise in sea levels which affects the GCC countries directly, as the natural and artificial islands in the Arabian Gulf will vanish, Bahrain would possibly lose up to 15 km of its coastline, all coastlines and marine life would be negatively affected, and desalination plants could be rendered unable to provide water. In her research on coral reefs in Abu Dhabi; [91] claims that the local marine ecosystem in the Arabian Gulf is substantially affected by climate change and must be placed among the ‘most stressed reef environments on Earth’.

Most developing countries have embedded climate change in their national security strategies, as the climate change issue has become an important topic in the UN, whose General Assembly passed a Resolution requesting ‘the relevant department of the UN to increase their effort in considering and addressing climate change’[92]. The first world conference related to the environment and climate change was held on 1997 in Kyoto, Japan. In the late 1980s, the UN established the IPCC, followed by the release of the first assessment report in 1990 at Rio de Janeiro. A total of 145 countries signed a UN Framework on Climate Change (UNFCC), followed by multiple meetings aimed at achieving the reduction of greenhouse gas emissions. On December 11, 1997, an agreement was reached by top officials from 160 nations on the Kyoto Protocol to the UNFCC. The commitment was extended internationally by signing the Kyoto Protocol treaty [93]. According to [9], the GCC countries ‘do not have any obligations at a national level to reduce emissions pursuant to the Kyoto Protocol’, although these agreements indicate the feasibilities of adopting the policy of using RE locally to reduce their carbon footprint.

[94] assessed the overall consumption of energy and its environmental consequences in the UAE. He found that although the UAE government deploys a plan to reduce energy consumption and greenhouse gas emissions, as well as to enforce environmental regulations on transport, industrial, commercial and residential sectors, energy consumption and environmental pollution are still not under complete control. He suggested that the UAE should invest in enhancing public awareness, reducing population growth rate, increasing economic growth, and utilizing RES, appropriate technology and energy management.

Policy evaluation and development in the context of ecological modernization and institutionalism (i.e. sustainability) was analysed to contribute to environmental policy development by [44], in order to provide a methodological approach to their examination of environmental strategy development in Abu Dhabi (UAE). They used case study methodology and postal questionnaire followed by telephone calls, semi-structured interviews with key informants from both public and private sectors, and analysis of the operation and behaviour of the Federal Environment Agency (FEA). The results show that the Abu Dhabi government has failed to develop an infrastructure for environmental protection; despite the fact that there is an existing policy, most participants were unaware of its contents. Therefore, they suggested that Abu Dhabi should promote more public participation in environmental decision-making and the development of policy.

3.3 GCC Countries' Approach to Environmental Sustainability

In 1981 the GCC countries aimed to increase their cooperation on the international and regional levels in all areas. Therefore, the Supreme Council declared the prominence of 'joint environmental laws and legislating national and regional capacities, training of labour force, raising environmental awareness among citizens and conservation of natural resources' [95]. Five years later in 1985, the Environmental Coordination Unit was granted the GCC Award for Best Environmental Work.

GCC countries are the major oil and natural gas producing countries in the Middle East and the world, distinguished by significant growth and development of infrastructure. In parallel, the electricity and water desalination sectors, which depend on oil and gas, have been facing remarkable growth. According to [73], the consumption of electricity in those countries has increased at a fast rate, by 12.4% from 2005 to 2009 (average 3.15% annually), from an average Watt per person in the GCC of 1149 in 2005, which was already almost three times the world average (297 Watt per person). The increase in the use of electricity is greater than the population increase, indicating more use per person (Figure 3.1). The rapid use and abuse of fossil fuels locally to generate electricity and sea water desalinization will decrease resource reserves and increase the emissions of harmful gases that could affect human health and harm the environment.

The general attitude in the international community is that the GCC countries are among the leading impediments to progress in reducing the human carbon footprint. Furthermore, all six GCC countries are among the top 25 biggest emitters of carbon dioxide per capita, with UAE and Kuwait leading the others [97],[5]. A comparison of 57 countries responsible for causing more than 90% of global energy-related CO_2 emissions found that Saudi Arabia ranked last in the Climate Change Performing Index (CCPI) for 2009 [98], and that while only 0.6% of the world population lives in the GCC, the region contributes 2.4% of greenhouse gas emissions per capita worldwide [99]. The Arab Forum for Environmental Development (AFED) [100] conducted a survey in 2009 covering 19 Arab countries to measure climate change perceptions among the public. The survey shows that 98% of those participants believed that the climate is changing, 89% of them believed that the change is generated by human activities, 51% of participants demanded that governments address the problem, 94% thought that their countries would benefit from participating in global action dealing with climate change, and more importantly 93% pledged to reduce their contribution to the problem.

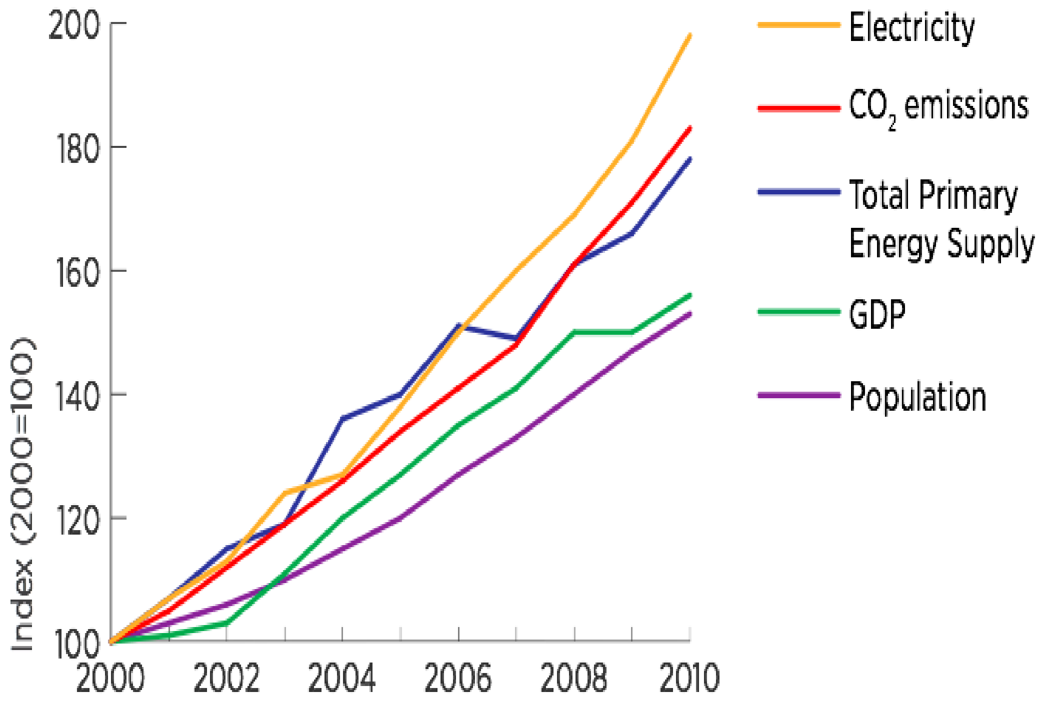

Figure 3.1: IRENA basic energy trends in the GCC [96]

Undoubtedly the carbon footprint of the GCC countries with respect to their population is significantly high [101], despite those countries falling in the high vulnerability category for the effects of climate change [99]. The serious impacts of the emissions generated by the consumption of fossil fuels on human health as well as on the environment have induced a number of initiatives undertaken by the GCC countries to improve environmental protection. The first initiative to develop strategies for future environmental activities within the GCC was in 1983 during the 6th session of the Supreme Council held in Muscat, whereby an environmental coordination unit was created and an economic agreement established the framework and roadmap to develop oil polices to be integrated in conjunction with other members of the world community. Furthermore, articles 9 and 11 in the first GCC economic agreement (of December 31, 2001) [102] concern the improvement of environmental quality:

> Article 9: ‘For the purpose of achieving integration between member countries in the field of petroleum and mineral industry and other natural resources, and in order to enhance the competitive position of member countries, the member countries shall adopt integrated policies in all facets of oil, gas and mineral industry to achieve optimal gains of, while at the same time taking into account environmental considerations and the interests of future generations’. [102]
>
> Article 11: ‘Member countries shall adopt the policies and mechanisms necessary to protect the environment according to all relevant legislation and resolutions adopted within the GCC framework, as representing the minimum level for national rules and legislation’. [102]

Over time, the GCC countries’ top government officials have taken steps to move their attention to clean sources of energy, as outlined below:

- In 1985, during the 6th Session of the Supreme Council (convened in Muscat), the first initiative to develop strategies for future environmental activities within the GCC was established.

- In December 1993, the final Declarations of the Supreme Council stressed the importance of cooperative environmental achievement for converging policies, legislations, enhancing nations and regional capacities, training of a labour force, raising environmental awareness amongst citizens, and preservation of natural resources.

- In 2001, the Economic Agreement established the framework and road map for the oil production policies that can be integrated in conjunction with other members of the world community.

- In December 2004, the final Declarations of the Manama Summit reiterated the point that conservation of the environment, renewing natural resources, and the protection of wildlife are crucial aspects of achieving sustainable development.

- In December 2007, the Supreme Council (28th session, Doha) approved the green environment initiatives encompassed by the GCC Environmental Action Act. Moreover, in the same year GCC countries agreed to contribute $750 million (US) to a fund for climate change research during the OPEC ministerial meeting.

In order to abide by their commitments, the GCC governments started to consider using alternative sources of energy locally that are renewable, clean, friendly to the environment, and harm-free to human health.

3.4 RE Establishments and Projects in the GCC

[103] claimed that RES in the Arab countries are not a priority for their governments; however, they added that since the late 1970s almost all Arab countries have included RE in their higher education curriculums, and have established research centres with relevant ministries, such as ministries of energy, electricity, water and environment. Table **3.1** shows RES in the Arab countries. Countries with low oil and gas reserves are notably advanced in the formulation of policies and plans for RE development (e.g., Egypt, Jordan, Syria, Morocco and Tunisia).

As stated previously, the GCC is largely dependent on revenues generated from oil and natural gas production. The GCC is still widely regarded as ‘one of the main actors impeding international climate change negotiations’ and ‘one of the top contributors to pollution in the world’ [104]. However, the GCC countries are starting a process of ‘environmental awakening’ by signing the Kyoto Protocol treaty, under the UNFCCC (2004) [105]. These agreements indicate the feasibility of aligning with the GCC policy of using RE locally in order to limit CO_2 emissions and the negative effects of climate change. Therefore, the GCC governments, the private sector, and the general public developed awareness for the important of making climate change a priority in the process of economic and social development

[3]. Because oil is becoming more scarce and expensive to extract, other sources of energy, including renewable ones, are eventually going to become priorities [106]. Consequently, GCC countries could transfer from being oil producers to being RE producers, and could ‘benefit from such projects financially, technologically, and ecologically’ [99].

Table 3.1: RE resources in the Arab Countries [103]

Country	*Energy Type*			
	Solar ($kWh/m^2/day$)	*Wind (m/s)*	*Biomass (mtoe/year)*	*Hydropower (MW)*
Algeria	5-7	2.8-4.1	1.66	0274
Bahrain	5-8	5-6	0.14	--
Egypt	5-9	4-10	3.9	2805
Iraq	5-6	--	6.3	2620
Djibouti	4-6	4-5	--	--
Jordan	5-7	5.5-7.5	0.74	7
Kuwait	5-8	5-6.5	0.37	--
Lebanon	4-6	3-5	0.59	0283.1
Libya	5-7	3-6	0.127	--
Mauritania	6	6-7	0.107	0061
Morocco	5-7	5-8	4.8	1205
Oman	5-6	4-6	0.47	--
Palestine	4-6	3-5	0.015	--
Qatar	5-6	5-7	0.07	--
KSA	6-8	4.5-6.5	3.0	--
Sudan	5-8	5-6.5	3.9	0303
Somalia	6-9	5-7	0.35	--
Syrian	5-6	4.5-11	1.24	1505
Tunisia	5-7	5-6	0.18	0066
UAE	5-6	3.5-4.5	0.33	--
Yemen	4-6	4-6.6	3.5	--

RE has the capability and the potential to play an important role in providing energy efficiency, and maintaining the sustainability of global resources. [107] stressed that GCC countries have favourable geographical conditions for RES. For wind power, Saudi Arabia and the UAE have inadequate potential (2.5–4.5 m/s), but Bahrain, Kuwait, Oman and Qatar have at least moderate opportunities (5–7 m/s). However, according to [108], the conditions for solar energy potential in the GCC are among the most favourable globally. He argues that if GCC countries decrease their local use of fossil fuels and depends on solar energy for their local electricity (allocating more oil and natural gas for export), the GCC will be among the best-prepared regions for the post-oil era. Moreover, reducing the use of fossil fuels will positively affect climate change, which in turn will improve the reputation of the GCC countries within the world community.

[101] coherently analysed the specific constraints and efforts obstructing the development of RETs in the Arab countries of the Gulf. Collecting data from international organizations, publications and expert contributions, the results of the implemented events in the region, twenty multiple-choice questionnaires were distributed to workshop employees and electronically-interviewed local operators. The study assessed the constraints preventing the development of RE opportunities in the GCC. Three constraints were identified: market technology (lack of commercial skill, scientific knowledge and experience, and awareness); policy legislation (i.e. the absence thereof, and the existing strategy not being well organized); and cost (existing governmental subsidies for oil and electricity are not complemented by similar support for RE, which is exacerbated by the high initial capital cost and unfavourable power pricing assessment of RE). Similarly, [9] stated that 'there is no instruction or framework at a GCC level government renewable policy or its implementation, both environmentally and socially common to all GCC countries, which in some instances, enhance but in others inhibit the potential RE'.

Although an absence of well-organized policies and strategies for promoting RE has been identified in the GCC [107], [109] stated that the GCC is ready to develop environmentally-friendly energy technologies due to the following reasons:

1. The GCC has great potential for utilizing RES, especially wind and solar energy;
2. GCC population distribution provides many benefits to remote villages from RES applications;
3. An important technological background appears based on search activities in the region. Applications of RES and the rational use of energy technologies (e.g. solar) have already been developed.

According to [107] [109], although GCC countries are facing rapid economic and social development, oil and gas will remain the major energy sources due to increasing demand and the lack of non-fossil energy resources. However, there are existing RES and Rational Use of Energy (RUE) activities. For example, King Abdul-Aziz City for Science and Technology (KACST) in Saudi Arabia conducts special research on solar energy, funds projects for Renewable Energy Sources Technologies (REST), and liaises with similar initiatives in the US, Germany, the

Kuwait Institute for Scientific Research (KISR), and the Middle East Desalination Research Centre (MEDRC), as a result of which a number of solar cooling systems were successfully installed. Omani manufacturers and industries utilize RE sources with Omani governmental support; Qatar joined the United Nations Conference on Environment and Development (UNCED) and established a link on RES and RUE technologies through an international database and encourages Qatari colleges and universities to conduct RE research.

[107, 108] studied the energy policies of GCC countries and their capacities to switch RE toward an ecological modernization. He claimed the GCC countries were found to be lacking a policy framework for RE and energy efficacy, but there are policies that developed on an individual project level. The GCC governments of UAE and Qatar have already been developing promising projects for setting up carbon exchanges. The UAE is seriously working toward reducing CO_2 emissions by 7% by 2020. This pledge is represented in a remarkable project called Masdar City in Abu Dhabi, which is scheduled for completion in 2016, which serves as the foundation for more efficient medium-and long-term activities in the field of RE. The City will be powered with zero-carbon and will depend completely on RE. The objectives of the City are:

> ‘To become home to a population of 90,000 made up of 40,000 residents and 50,000 daily commuters. The city hopes to attract more than 1500 companies in the field of sustainable energy technologies to have offices and research centres within its city walls. By the fall of 2009 the first students will start to study at the Masdar Institute of Science and Technology. The institution’s curriculum includes courses in the areas of information technology, water and environment, engineering systems and management, materials science and engineering, mechanical engineering as well as its research activities. Masdar City will also host the secretary of the International Renewable Energy Agency (IRENA)’. [104]

Moreover, according to [106], education and technology are predicted to be the major advantage of Masdar City; the well-stated ‘green’ standards and regulations and low oil prices have a ne6gative effect on it. Doha and Dubai have an interest in setting up carbon exchanges; Dubai is establishing green-building practices based on the United States Green Building Council's leadership in Energy and Environmental Design rating system. The Energy City in Qatar will be the headquarters of natural gas and oil companies for the purpose of generating a sustainable plan for development and incorporating the latest green technology and solar energy.

Sustainable or environmentally friendly building in the Kingdom of Bahrain is represented in two towers using Bahrain International Circuit (BIC) to diversify the electricity supply with the addition of solar radiation, solar heat, and wind turbines to assure its sustainability and to reduce CO_2 emissions. Because 60-70% of the total energy utilization in the Kingdom of Bahrain goes to buildings and construction According to [110], Bahrain:

'has set targets for reducing environmental impacts from building and use of energy, through the Energy White Paper; they have also applied a climate-change levy on carbon-emitting fuels and support the use of RE through the renewable obligation'.

They discussed a model for calculating the suitable building index to be able to evaluate the potential of the society for building integrated photovoltaic or building integrated wind turbines in Bahrain. The test shows that the sustainable building index scored 0.47, which identifies the need to develop policies on RE, RE education, continuous efforts on building more integrated photovoltaic or wind turbines, and public environmental awareness. The study lists 15 barriers to RE in Bahrain: high capital cost and long payback, ignorance and lack of understanding, perceived risk, incompatible site, confused policy and planning constraints, unproven technology, maintenance and complexity, variance, stubbornness of energy industry, environmental and ecological impact, lead time in construction, and expensive design fee [110]. The study also observes that the King Abdullah University of Science and Technology in Saudi Arabia is building a sustainable campus with the implementation of several green technological innovations. However, the study concludes that the GCC countries will evade structural changes for RE innovations due to political reasons.

In OPEC 2007, the GCC countries pledged $750m (US) to fund carbon capture and storage research. Considering the post-oil age and the increasing demand for electricity (by 7.3% annually), the GCC governments are increasingly including environmental sustainability and RE in their longer-term development plans to help establish sustainable and alternative sources of energy. [111] identified several challenges facing the development of RE technologies in the GCC, such as the low price of fossil fuels, on-going investments in oil exploration and refining, and the lack of political interest. Therefore, the study encourages GCC governments to put a price (i.e. tax) on pollution, reduce externalities, and provide a more competitive policy for alternative energy producers.

[112] assessed the potential of and barriers to RE resources in Oman. They found that 99% of Omani power generation and its economy depends heavily on gas and oil resources, which makes it imperative that Oman look for alternative energy resources (most likely solar and wind energies). In Oman, RE 'is dependent mainly on political support' [112], this is applicable to all GCC countries. Recently, Sultan Qaboos University for Science and Technology's Department of Research and Development created a curriculum and a local and international research and networking infrastructure for research and education on RE. Wind and solar RE in Oman have some advantages and disadvantages:

1. Wind energy is considered a promising source of energy in Oman; therefore in 1996 Oman developed its first 10kW wind-powered, electrical water-pumping system to evaluate the use of wind power to pumping the groundwater. However, the present gas price compared to the price of wind energy from the highest wind potential in Oman is not economical ($3 and $6 M respectively).

2. Solar energy in Oman can create a substantial amount of energy but this is dependent on the season (i.e. more in summer, less in winter). Oman is inviting specialized consultants to build a major solar power plant.

[112] concluded that there is a need for the Omani government to provide 'adequate regulation supports' to encourage investment, to reinforce public awareness, and to seek international expertise and advisory services for RES and technologies.

Future potentials of RE applications in the leading oil producer, KSA, were reported by [113], who found that the most sufficient and natural RES available are wind power and solar radiation. The results of analysing both sources of energy show that wind energy has not yet been fully explored and needs more experience and expertise in the field; however it could be profitably used for local and small-scale applications. Only low and medium solar thermal energy applications are technically and economically practicable in KSA. Finally, they urge the government to establish a link between regional RE research and local centres, to establish government subsidies, increase public awareness of utilizing RE, and encourage educational institutions to establish RE educational programs, degrees in the field, and training sessions.

After a long meeting with top officials at the GCC, [114] declared that GCC economies are highly concentrated on hydrocarbons, requiring strong policy initiatives and closer involvement of governments to promote RE projects, especially solar and wind powers, to help prevent electrical shortages. Although there is a lack of clarity about government policies on RE initiatives, according to her, the GCC government stakeholders must work closely with the private sector to create stable long-term investment.

3.5 Wind and Solar Sources for RE in the GCC

The harsh environment of the GCC countries is well-suited for RE, especially solar and wind resources. Within the GCC there is almost universal high exposure to solar radiation during the daylight hours, and approximately 1,400 hours per year of full-load wind and high wind speed (Table 3.2).

Table 3.2: GCC countries' exposure to solar radiation and wind [73]

Country	Global solar radiation (kWh/m^2 per day)	Direct normal solar radiation (kWh/m^2 per day)	Hours of full-load wind per year
Bahrain	6.4	6.5	1360
Kuwait	6.2	6.5	1605
Oman	5.1	6.2	1463
Qatar	5.5	5.6	1421
KSA	7.0	6.5	1789
UAE	6.5	6.0	1176

According to [9], solar radiation levels throughout the GCC are equivalent to or greater than levels of solar radiation in areas where there are solar photovoltaic (SPV) as well as solar thermal technologies, indicating that the GCC are exceptional candidates for the introduction of this technology, in addition to the full load of wind which is more or less than 1,400 hours per year with the use of wind power generation technologies. They claim, however, that GCC countries had no desire to promote RETs due to a lack of compelling political and economic grounds until relatively recently [9]:

> 'Politically, the region's leaders have heeded an international push rallied to-date around the Kyoto Protocol to reduce greenhouse gas emissions and enhance energy security by diversifying the global energy base. Economically, to the extent that alternative or supplementary energy sources can compete with traditional power generation'.

They concluded that there is an energy shortage within the GCC countries but they have the financial resources to overcome it, and there is now a positive attitude, awareness, and acceptance of the implementation of RETs. RETs are expensive, therefore they stress that GCC countries should increase the involvement of the private sector, work with tax and customs exemptions, bind capacity targets by installation of renewable power generations, offer financial support in the form of subsidies, find land concessions for installation, and support the operation of RE generation plants. [111] stressed the need to think beyond oil for GCC countries, supported by evidence that the GCC can develop both solar and wind energy 'to diversify its energy portfolio, reduce carbon emissions, and preserve precious fossil fuels for greater export revenue'. He claimed that solar energy can be developed because of the daily average of nine hours of sunshine, low levels of rainfall, low cloud cover, and large abundance of space (about 98.3% empty deserts) to develop large-scale energy projects. In terms of wind energy, according to [111] the GCC countries could not reach the average wind speeds across overland area to generate economically feasible wind energy; the average speeds across overland regions in the Gulf are in the range of only 4.5-5.5 m/s. The most favourable site for wind is along the Red Sea coast to the south.

As stated previously, UAE and Qatar are the leading GCC countries in utilizing RE; albeit Saudi Arabia had an RE initiative from the early 1960s, this was never followed through due to lack of political support [111]. Additionally, the three built-in wind turbines that Bahrain is expected to construct will help generate 15% of its energy needs, and power a lighthouse.

Table 3.3: Essential comparisons for analysing solar power potential in GCC [116]

State	Avg. max. day temp. (^oC)	Avg. min. night temp. (^oC)	Av. daily hrs. sunshine	Total rainfall per year (mm)
Dubai	33.3	21.8	9.5	57
Qatar	32.4	21.8	9.5	74
Kuwait	32.2	19.3	8.9	111
Bahrain	30.8	22.5	9.3	84
Oman	32.8	23.4	9.6	103
KSA	33.0	18.4	9.3	112

Table 3.4: Essential comparisons for analysing wind power potential in GCC [111]

State	Wind probability (Beaufort scale) (%)	Average wind speed (m/s)
Dubai	36	5.0
Abu Dhabi	38	4.9
Doha	29	4.8
Bahrain	39	5.3
Kuwait	45	5.8
Muscat	15	3.8
Dhahran	40	5.5

3.6 Administrative and Technical Barriers to RE in the GCC

Like any technology, RET faces various economic, social and technical barriers in the GCC. Furthermore, there is a lack of reliable local data from the GCC countries regarding the diffusion and development of RE. [3] analysed the specific constraints and efforts that obstruct the development of RE in the GCC countries. Through the use of data from international organizations, publications, contributions of experts, results of implemented events in the region, 20 multiple-choice questionnaires from workshop employees, and electronically-interviewed local operators, the study assessed the constraints preventing the development of RE opportunities in the GCC. The results are categorized into three categories of constraints: 1) market technology – such as lack of commercial skill, scientific knowledge and experience, and awareness; 2) policy legislation – which is mostly absent, and the existing strategy is not well organized, plus there is an absence of a relative legal framework and agreements for the promotion of lRE; and 3) cost – which represents in the existing governmental subsidies for oil and electricity that do not exist for RE. [9] claimed that there is no instruction or framework at the GCC government level for renewable policies or legislation for implementation.

[110] reported that Bahrain ‘has set targets for reducing environmental impacts from building and use of energy through the Energy White Paper. They have also applied a climate-change levy on carbon-emitting fuels and support the use of RE through the renewable obligation’. In their study, they discussed a model for calculating a suitable building index to evaluate the potential for building integrated photovoltaic or building integrated wind turbines in Bahrain. The test shows that the sustainable building index scored 0.47, which led the researchers to recommend the Bahraini government should establish policies for RE, RE education, continuous efforts on building integrated photovoltaic or wind turbines, and public environmental awareness. The study lists fifteen barriers to RE in Bahrain (listed above) [110].

Moreover, [115] examined the potential use of building integrated photovoltaic (BIPV) in the GCC. Through the use of a large-scale online questionnaire administered to 244 stakeholders (defined as homeowners, academicians, building developers and architects in the GCC; nine participants of the 244 were interviewed via telephone), the study showed that even though they acknowledged the high electricity consumption in their houses, half of the homeowners who participated in the questionnaire had no knowledge of the phenomenon of global warming nor were they concerned about recent negative impacts of fossil fuel energy on the environment. Their apathy was related to the fact that electricity was provided cheaply (and in some GCC countries, free of charge). The academicians were more aware and strongly agreed that the GCC should utilize RE technologies to help the environment. However, they believe that high cost is the primary obstacle to the effective diffusion of PV, suggesting that the GCC governments should start reducing the heavy subsidization of the price of electricity generated using fossil fuels, teaching the subject of RE and its benefits to the environment in their universities and colleges, and increasing public awareness about the development and deployment of RE technologies.

[116] found that Oman is encountering policy and administrative barriers, including highly subsidized, cheap electricity competing with RE technologies, lack of fiscal incentives to consumers for installing RE technologies, and lack of trustworthy information related to worldwide and regional RE. These can lead to difficulty identifying technical opportunities in overcoming obstacles related to the

performance, cost, and overall reliability of the systems, and a lack of accurate information and data about the potential of using RE. The study concludes that there is insufficient financial support for better RE technologies.

Having mentioned all of the above, the most important current challenges to the implementation of RE, especially solar energy, are:

1. Cost

- Cannot compete with conventional power generation due to heavily subsidized water, fuel, and electricity.
- Low electricity costs fail to incentivize consumers to efficiently use energy.
- Land availability is scarce in places like Qatar and Bahrain, which would increase costs.

2. Environmental effects

- Direct solar radiation is reduced due to dust.
- PV systems are negatively affected by high ambient temperatures.
- Reduced performance of CSP system due to high humidity.

3. Infrastructure

- Grid-tied RE system is not permitted in some countries yet.
- Most grids in other countries are not well-equipped to handle the dynamics of solar energy systems.

4. Public awareness

- Lack of awareness of the public with regards to the real economic and environmental costs of power generation.
- Understanding of climate change and its negative implications are slowly developing.

5. knowledge

- Limited factual data available on real-life performance of solar systems, including weather data.
- Limited R&D resources to develop and adapt solar technology to the GCC's exceptional climate circumstances.

3.7 Environmental Barriers to RE in the GCC countries

As stated previously, the negative impact of dust on solar panel technology has been a major concern for most GCC countries [117], [118]. Many researchers studied the sources and characteristics of dust storm events over the Arabian Gulf and the Arabian Sea region using multi-satellite observations and ground-based measurements. Satellite-based measurements are more precise, due to the fact that ground-based measurements are limited in space and time [119], [120]. The massive open area of the desert enables the wind to shift dust up to a thousand kilometres from the source region. This action plays a crucial part in the regional and global radioactive balance in the Earth [121]. Due to the nature of the land in the Arabian Gulf region, dust storms are a major environmental problem in this part of the world.

Dust storms occur mostly in the spring and summer months because of the strong north-westerly winds known as *Shamal* [118]. Waves of high pressure are the reason behind the *Shamal* wind, which travels through the Persian Gulf between Saudi Arabia and Iran. Figure 3.2 shows the sources of sediments in the Northern Region of the Arabian Gulf [122]. Figure 3.3 shows satellite images of a dust storm passing over the Arabian Gulf [123].

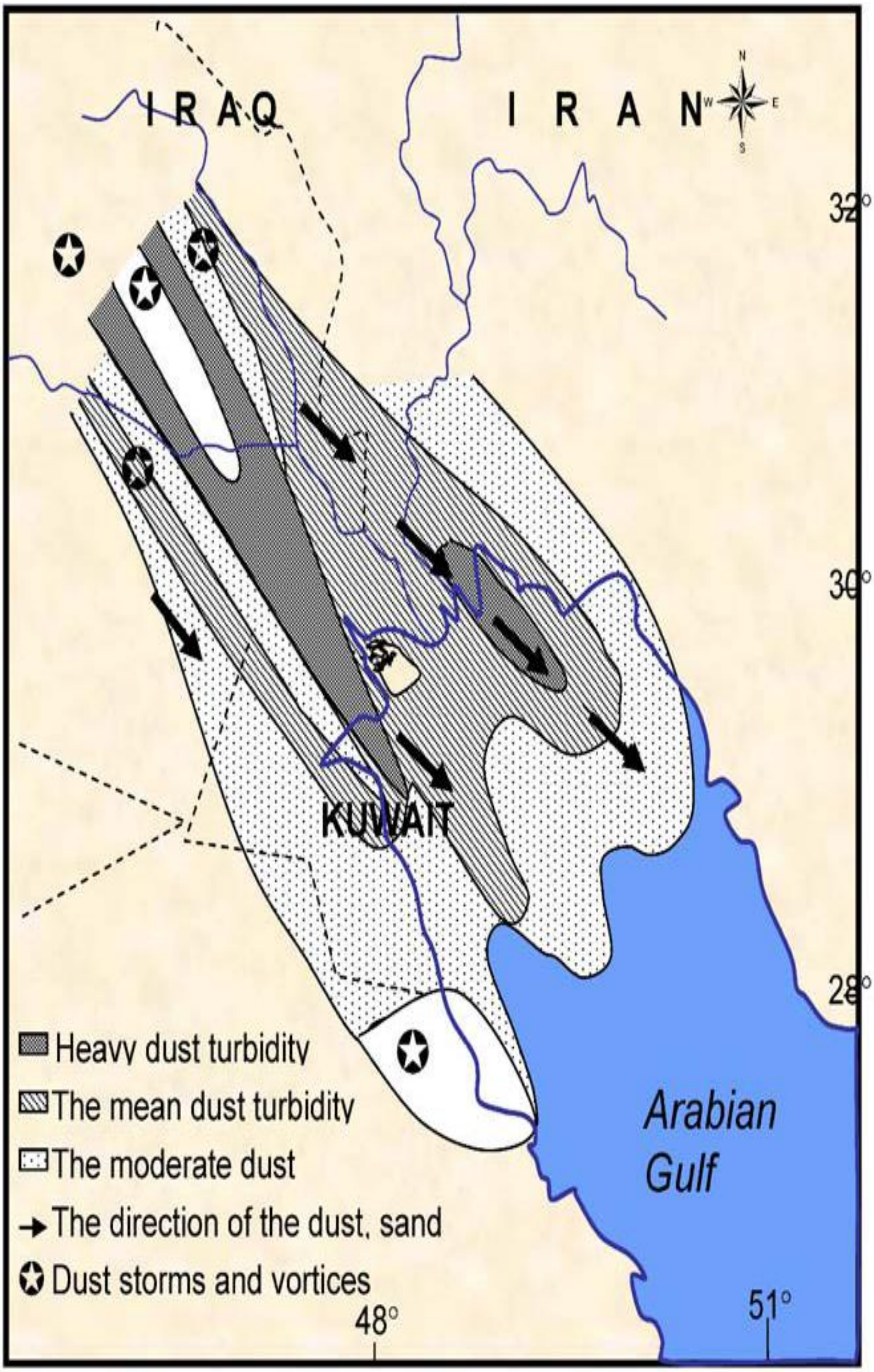

Figure 3.2: Sources of sediments in northern region of Arabian Gulf [122]

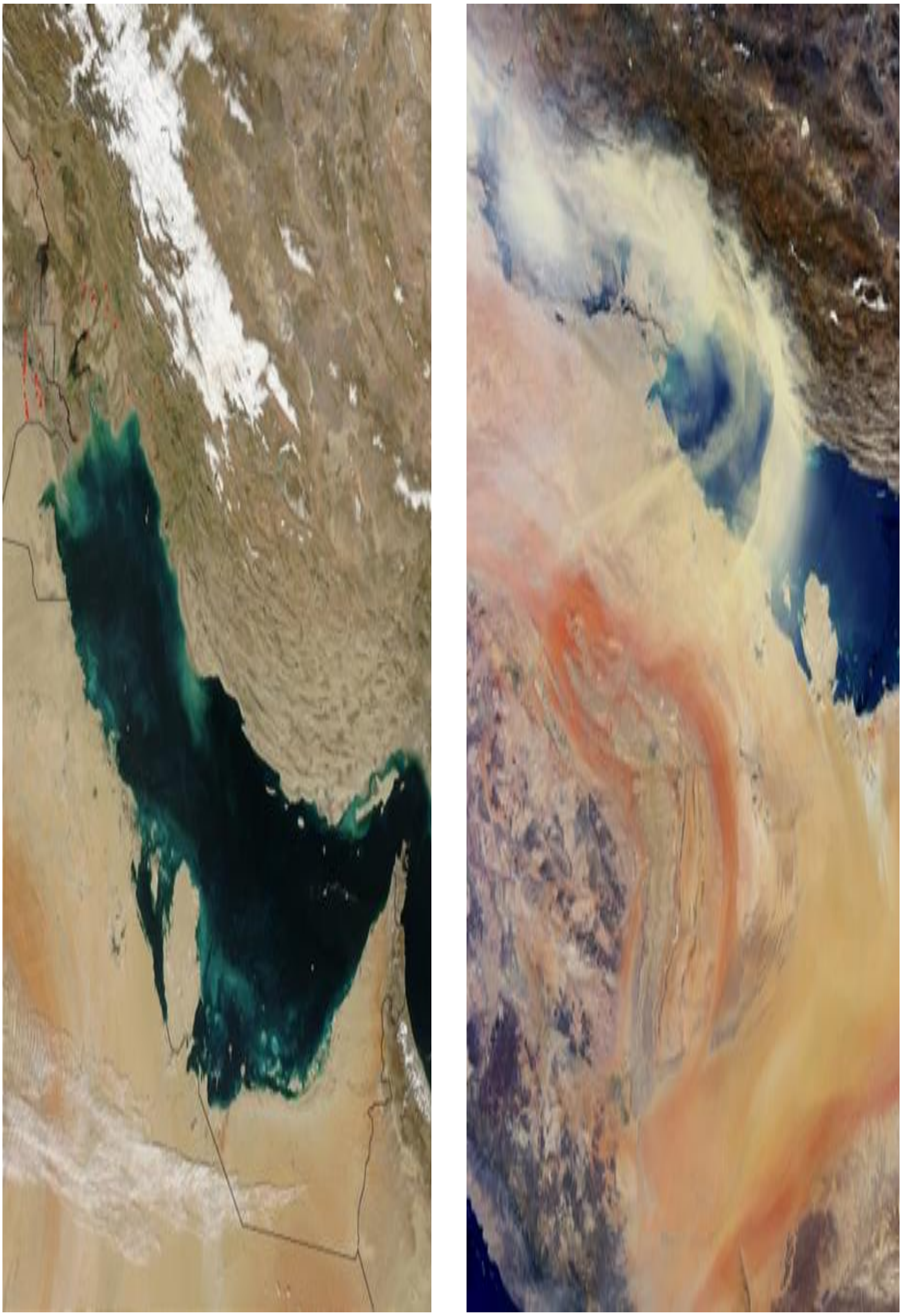

Figure 3.3: Satellite images of dust storm passing over the Arabian Gulf [123]

3.8 Investigating Technological Solutions for Dust Accumulation on Solar Panels in the GCC

Many researchers have attempted to find a solution to dust accumulation in order to increase the efficiency of solar panel technology. According to [124], natural power sources could be used to remove dust, such as wind power, gravitation and rainfall; however, such methods are not efficient. Previous studies claimed that oblique or vertical positioning of solar cell arrays helped reduce dust in the early morning, late evening, night, and on rainy days; however, rotations of large solar cell arrays are challenging [125, 126].

In Kuwait, [127] analysed the impact of dust accumulation on tilted glass plates with angles ranging from 6-60^o. The results show a decrease from 64% to 17% in plate-transmittance tilt angles ranging from 0^o to 60^o correspondingly after 38 days of disclosure. Moreover, a 30% reduction in useful energy gain was detected by the horizontal collector after three days of dust accumulations. [128] examined the impact of long-term dust accumulation on the energy output of PV array near Riyadh. It was found that for an array tilted at 24.6^o, the monthly energy yield decreased by 32% for a non-cleaned array after eight months compared to one cleaned daily.

Another study [129] claimed that mass accumulation of PV power in Kuwait fell 17% in six days. It also found that the impact of dust accumulation was heightened in spring and summer (20% over six months). [127] studied the effects of dust on solar flat-plate collectors. The experiment was conducted using seven flat plate collectors; six were arranged in three pairs and subjected to various inclinations of 0^o, 30^o and 60^o. The seventh collector was vertically positioned at 90^o. Within each pair one was cleaned regularly while the other two were not cleaned. Later, the amount of absorbed solar energy of the clean and unclean plates was measured; results indicated accumulations of 2.5 g/m^2/day between the months of April and June.

[130] wind tunnel experiments were conducted to investigate whether wind velocity and air dust concentration influenced the performance of PV cells showed that the deposition of fine dust particles on the cells greatly affected their performances. Another study was carried out in UAE by [131] to evaluate the impact associated

with seasonal dust depositions solar collectors within a desalination plant as well as the frequency of cleaning to enhance the collector's performance. The study came to a conclusion that seasonal dust deposition and performance of solar collectors within a desalination plant are not correlated. Based on the results, the study found that the end-of-month transmittance drop varied between 2 to 4% in months of winter i.e. November to December and 6 to 16% in summer times i.e. May to August. As such, it was concluded that frequent cleaning is necessary.

Basically, such factors like the type of climate, PV material and inclination, specific time of the year, the dust period, and the devices used for cleaning had a profound effect on the performance of solar panels. The table below represents the factors influencing the performance of solar panels.

Table 3.5: Factors of solar panels

Factor	*Remarks*
PV incline	Horizontal PV setting attracts more dust accumulation than vertical setting.
PV material	Plastic films attract more dust than glass.
Climate type	Tropical climates (heat and humidity) cause more dust than other climate types.
Time of year	Dust in the GCC is more likely to occur in the spring and summer.
Dust period	Dust accumulation has a positive correlation with the time.
PV device cleanliness	Dust accumulation has a negative correlation with the regular cleaning of the PV devices.

[124] was carried to investigate the various mechanical methods used to clean solar panels. This included such methods like air and/or water blowing (Figure 3.4), brushing (Figure 3.5), vibrating and ultrasonic driving. Basically, in brushing method, equipment's like a conventional broom or brush that is driven by a rotor and assumes the design of a typical windscreen wiper are used. This was however found to be ineffective majorly due to their small sizes and the extent of dust on the panels. As such, based on the environment at which the solar panels are located, the maintenance of the machine is thus rendered uneconomical. In addition, the power of the machine is highly dictated by the size of the solar panels which in this case are considered to be very large covering wide area. Lastly, the process of wiping by using the brushes can result into scratches within the surfaces of the solar panel thus affecting its effectiveness.

Based on the fact that dusty environments are considered as the major challenge hindering NASA's exploration missions, Kennedy Space Centre has engaged in programs aimed at developing technologies that can help in alleviating the challenge.

In this regard, Dust Shield is regarded as a dust removal system that utilizes electrostatic and di-electrophoretic forces in removing dust that has already been deposited on the panel surfaces [132]. The technology is basically based on the concept of electric curtain that was developed at NASA by Tatom in 1967 [124] and further by Masuda at the University of Tokyo in 1970 [133]. It has been proved that the technique has the capacity to lift and as well transport charged and uncharged dust particles by the use of electrostatic and di- electrophoretic forces [134].

Basically, the concept comprises of a series of parallel electrodes connected to an AC source that produces a travelling wave and acts as a contactless conveyor and can be enhanced with a three-phase system. The dust particles are thus repelled by the electrodes that are used in generating a magnetic field and travels along or against the direction of the generated wave. As such, the researchers were able to conclude that the system was able to protect rigid transparent surfaces such as solar panels, windows and optical filters, metallic surfaces; rigid open dielectric surfaces; and fabric spacesuits.

In the instance that the energy consumption rate that is required to operate an electric curtain together with its power supply is equal or higher than energy capturing rate of a solar panel this implies that the system is not efficient in maintaining constant operation of the electric curtain for cleaning the panels. [135] indicated that a control scheme for subsequent activation and deactivation of the electric curtain is vital in achieving optimal net energy that is captured. As such and in order to activate and deactivate the system, threshold voltage based on the voltage of a clean panel was used. The electric curtain activated when the panel output voltage decreases to a fraction *V*on (voltage on) of the clean panel output voltage and deactivated when the panel voltage exceeds a second output voltage fraction *V*off (voltage off) as indicated in figures 3.6-and 3.8. The tables below represent methods used to clean dust from solar panels and their associated merits and demerits.

Figure 3.4: Dust removal using water blowing method

(http//www.cesusa.com)

Figure 3.5: Dust removal using brush method

(http//www.rsc.org)

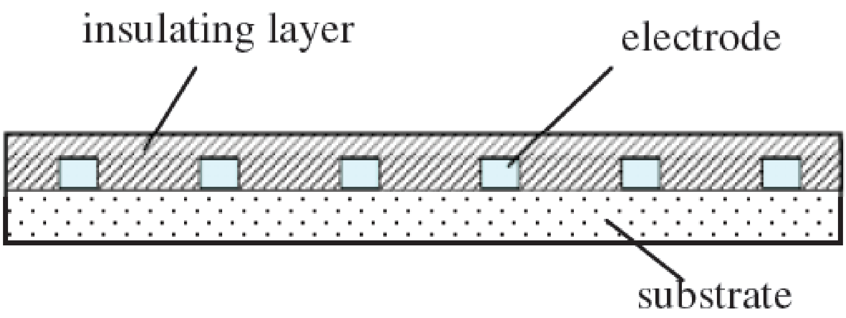

Figure 3.6: Basic structure of electric curtain [124]

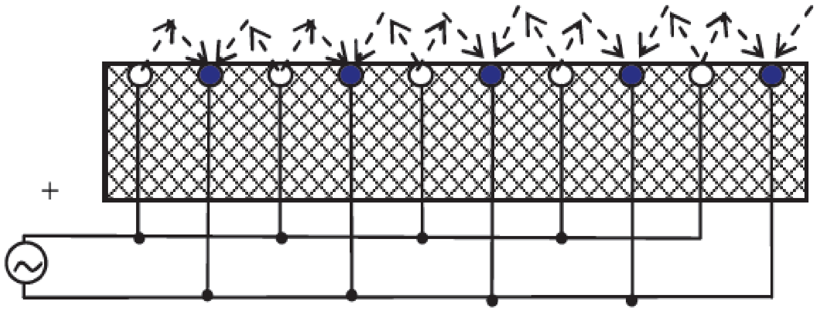

Figure 3.7: Single structure of electric curtain [124]

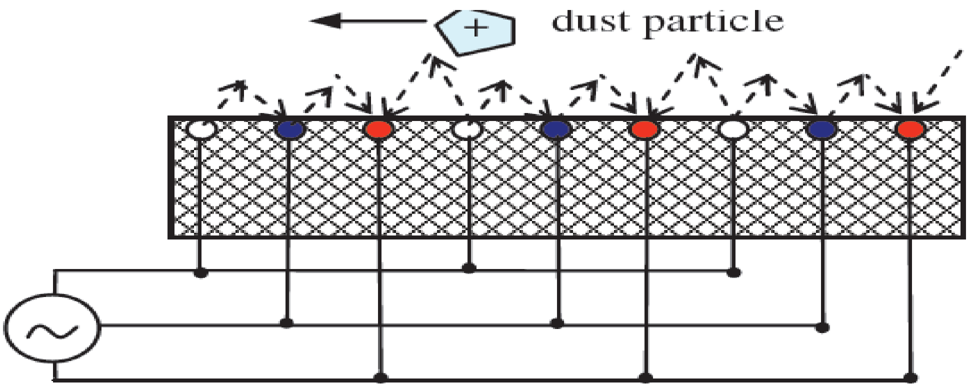

Figure 3.8: Three-phase electric curtain [124]

Table 3.6: Pros and cons of methods to clean dust from solar panels

Technology	*Pros*	*Cons*
Water spraying	Simple to maintain. No electricity consumption.	Only clears a portion of dust located on the panel. Water is not an abundant source in the GCC.
Wet scrubbers	Simple to maintain. Water towers use minimal electricity.	Water is not an abundant source in the GCC. More prone to mechanical failures.
Static electricity	Efficiently clears dust from solar panels.	Uses a stable source of electricity
Electric curtain	Effectively clears dust from solar panels.	Not efficient if the energy consumed is greater than the energy produced by the panels.
Electric curtain + activation/ deactivation control	Most efficient. Effectively clears dust from panels, and maintains energy consumption automatically.	Uses minimal electricity sources.

3.9 Energy Generation in Kuwait and Renewable Energy

Kuwait is situated in the Arabian Peninsula at the Northwest corner of the Arabian Gulf between 28^{o} and 30^{o} latitude, 46^{o} and 48^{o} longitude. It shares borders with Saudi Arabia to the south, and Iraq to the north (see Figure 3.9). It has an approximated total land area of 17,818 km^2 with majority of it being flat and slopes gradually towards the sea to the east. The areas to the western borderland are 270 metres above sea level. The country's population occupies about 6% of the total land. It was estimated that the local population would be 3.5 million towards the end of 2010 based on annual growth rate of 5.9% for the last 10 years [136]. The gross domestic product (GDP) is US $135bn with a growth rate of 4% and relative stability [137]. The climate is characterised by hot, dry and long summers and warm, sometimes wet, short winters. During the summer dust storms are frequent, due to increased humidity. Extreme temperatures occur between 0 to 50^{o}C in winter and summer periods respectively [138, 138]

Figure 3.9: Map of Kuwait [139]

The major source of energy in the country is obtained from oil and natural gas. Basically, these resources are entirely managed by the Kuwait Petroleum

Corporation (KPC), a stated-owned entity responsible for oil and gas production, manufacturing, exportation, and distribution of oil and gas products. The energy sourced from these resources is majorly for production of electricity that is used locally and in water desalination. In addition, industrial and transportation sectors consume about 65% and 20% while the rest is consumed locally [138, 138]. Generally, the generation of electricity majorly depends on oil, oil-refined products and gas fuels which are entirely produced by KPC. Currently, the total installed capacity is approximated at 450 million imperial gallons per day [138,138].

As a result of high growth in population, the need for new infrastructure in meeting electricity and water demands has grown significantly. As [140] indicates, residential buildings are considered as the highest consumers for electricity reaching to about 70% of the total electricity generated. As such, the current technologies employed in energy production lack the capacity to meet the needs of the consumers thus requiring installation of conventional power plants [141]. Based on the fact that these power plants are regarded as the major consumers of oil and gas, it is estimated that the consumption within these plants alone would reach about 26.5% of the total Kuwait oil production by 2020. In regard to the 2008 oil production rate, it has been shown that all produced oil within the country will be totally consumed locally by the year 2027 [142].

In consideration of the fact that the country has extensive welfare programme on the basis of the income generated from oil and gas and the increasing consumption of oil in generating local electricity, the country faces serious threat in future in terms of energy security as compared to other countries especially if it does not diversify its energy sources i.e. adopting sustainable energy strategies. This is further complicated by the amounts of toxic emissions generated which have serious impact both to the environment and the humans. As [143] shows, the per capita carbon dioxide (CO_2) released within the country is amongst the highest in the world. Currently, the amount of CO_2 released as a result of electricity generation and water desalination is estimated at 40 million tons per day and which is expected to rise to around 70 million tons per day by 2030.

Basically, it has universally been agreed that fossils fuels will come to an extinct in the near future. Therefore, there is the need to engage in extensive research for viable solutions in regard to the raging energy crisis especially and more so high focuses on sustainable energy sources that are both renewable and environmentally friendly. This may include focusing on such renewable energy sources like solar, wind, tidal, geothermal, deep earth, and atomic energy in the production of electricity as clearly explained by [144]. Thus:-

1- Near depletion of the world oil reserves; the Middle East alone holds two-thirds of its stock and proven estimates show the remainder is approximately 148 billion tons.
2- Expectation of continuous increase in global energy consumption with a prediction of 40% increase in energy demands by 2025.
3- Assurances and warnings from environmental researchers about the harmful implications of burning huge amounts of fossil fuel reserves (oil, gas and coal) which results in massive emissions and harmful gasses that causes damages to all forms of life.
4- The need for action and respect of the provisions of the Kyoto Protocols which calls for signatories to reduce GHG emissions in order to mitigate the acceleration of global warming.
5- Under the circumstances, rapid changes must be introduced; the current warnings of experts and scholars need to contribute to a balanced plan to secure the country’s current and future energy needs based on alternative and renewable energy sources.

The alternative sources that can play the most positive role in substituting part of the oil and gas fuels are RES. A renewable resources assessment study found that solar and wind energies are the most promising solutions for Kuwait [145].

3.10 Electricity Generation and Consumption in Kuwait

The primary sources of electrical energy generation and fresh water in Kuwait are driven by petrochemical energy. The conversion of primary energy generated by the fuel into electrical energy is a multi-stage procedure, which requires complicated equipment and huge financial investments in infrastructure. Funds are allocated towards purchasing colossal boilers that will burn large quantities of fuels, which are consequently transformed into chemical energy, which in turn rotates electrical generators and transforms mechanical energy into electrical energy. This electrical energy is exported to the network for transmission, distribution, and finally delivery to the consumers [144].

Due to the increase in population and the urban expansion resulting from new housing cities, a notable increase in electricity consumption has occurred in Kuwait. Currently, Kuwait has seven plants for generating electricity, with a total capacity of 13.23 thousand megawatts [144]. The annual electrical consumption is currently about 11 thousand megawatts, and it is expected to increase to 25 thousand megawatts by 2030 (KPC, 2013).

According to the Statistics Department and Information Centre in the Ministry of Electricity and Water (MEW) [144], in 1951 the number of consumers totalled 2462; it went up to 47,060 in 1960. Over a decade by the end of 1970, the number jumped to 118,682, increasing to 217,232 by 1980, an increase of 83% from 1970. By the end of 1989, the number of consumers totalled 260,135 while in 1991 it decreased to 195,534 as a consequence of the Iraqi invasion and Gulf War. From 1992 onwards, the number of consumers started increasing until it reached 452,265 by the end of 2011. This means it is gradually returning to its normal average (Table 3.7).

Table 3.7: Total increase in consumers and the increase in energy generation [144]

Year	Total Consumers	% Increase/ Decrease of Consumers	Electricity Energy Generation (MW)	% Increase/ Decrease of Electricity (MW)
1992	198079	-	16885	-
1993	200804	1.4	20178	19.5
1994	205584	2.4	22802	35.0
1995	230549	12.1	23724	4.0
1996	240614	4.4	2575	7.4
1997	245634	2.1	26724	4.9
1998	253688	3.3	29984	12.2
1999	257012	1.3	31576	5.3
2000	316693	23.2	32323	2.4
2001	330125	4.2	34299	6.1
2002	321009	-2.8	36362	6.0
2003	359660	12.0	38577	6.1
2004	371031	3.2	41257	6.9
2005	375430	1.2	43734	6.0
2006	399554	6.4	47605	8.9
2007	424781	6.3	48754	2.4
2008	432852	1.9	51749	6.1
2009	441478	2.0	53216	2.8
2010	449236	1.8	57082	7.3
2011	452265	0.7	57489	0.7

3.11 Current Power Generating Units

Crude oil, gas oil, heavy fuel oil and natural gas are all abundant fossil fuel resources used in Kuwait to generate energy in power plants. Natural gas is generally favoured for logistical and economic reasons, depending on the boiler design. In case of emergencies (e.g. regional turmoil), natural gas and gas oil can be burned by older plants, while newer plants are designed to be able to burn four types of fuel. The six power plants in Kuwait and their capacities are shown in Table 3.8. Gas turbine units are used for smaller capacities, such as 18 MW in the Doha East Power Station, 42 MW in the Shuwaikh Station, 28.2 MW produced in the Doha West Power Station, 27.75-165 MW produced in the Az-Zour South Power Station, 41.7- 62.5-220 MW in the Sabiya Station, and 220 MW in the Shuiaba North Station. The sum of all the power capacity produced is 4957.2 MW at high temperature operation. The units mentioned were designed for the typical normal peak load operations with blackout start capability within ten minutes, compared to the five hours that are normally required by steam turbine units. Massive investment in, and development of infrastructure and the rapid increase in population have compelled the MEW, despite being remote and far away from the industrial centres of supply, to be capable of keeping pace and meeting the ever-increasing electrical demand of the power stations' available capacity (MW) at the end of 2011.

3.11.1 Steam Turbine Units

Current steam turbine units comprise varying capacities, ranging from 134 MW to 300 MW in all power stations. The sum of installed capacity of these units is 9745.5 MW. These units comprise the largest capacity units, all operated to the system's power demand. The available and operational capacity is usually maximized in summer seasons as the demand for electricity increases with temperature rise. It is usually minimal in the winter season; therefore, annual maintenance usually takes place in the winter season.

3.11.2 Turbine Units

Gas turbine units are used for smaller capacities, such as 18 MW in the Doha East Power Station, 42 MW in the Shuwaikh Station, 28.2 MW produced in the Doha West Power Station, 27.75-165 MW produced in the Az-Zour South Power Station, 41.7- 62.5-220 MW in the Sabiya Station, and 220 MW in the Shuiaba North Station. In high-temperature operating conditions, the sum of all the power capacity produced is 4957.2 MW. These units were devised to meet normal peak demand and they have ten-minute blackout start capability, compared to the five hours that are normally required by steam turbine units. Massive investment in and development of infrastructure and the rapid increase in population have compelled the MEW, despite being remote and far away from the industrial centres of supply, to be capable of keeping pace and meeting the ever-increasing electrical demand of the power stations' available capacity (MW) at the end of 2011.

Table 3.8: The six power plants in Kuwait and their capacities [144]

Station	Current Available Capacity				Total Available Capacity
	Gas Turbines		Steam Turbines		
	Capacity/ Unit	Total	Capacity/Unit	Total	
Shuwaikh	6*42	252	-	-	252
Shuaiba South	-	-	6*120	720	720
Shuaiba North	3*220	660	1*215.5	215.5	875.5
Doha East	6*18	108	7*150	1050	1158
Doha West	5*28.2	141	8*300	2400	2541
Az-Zour South	8.130 4 × 27.75 5 × 165	1040 111 825	8 × 300 2 × 280	2400 560	2936
Sabiya	6 × 41.7 4 × 62.5 6 × 220	250.2 250 1320	8 × 300	2400	4220.2
Total		4957.2		9745.5	**14702.7**

3.10 Energy Subsidies: Definition and Rationale

The literature understands the concept of subsidy in energy sources and power generation as:

> 'any government assistance, in cash or in kind, to keep prices for consumers below the market level for which the government receives no equivalent compensation in return, but conditions the assistance on a particular performance by the recipient' [146, 147].

[148] explained the rationale for energy subsidies using several objectives: 1) energy poverty, the lack of household access to electricity for cooking and heating (the UNEP announced that 1.6 billion people have no access to electricity; 65 million of these are from the Arab World); 2) protecting the poor from high fuel costs; 3) fostering industrial development to induce firms to provide their goods and services

to consumers at reasonable price, to help protect local industries and employment; 4) political considerations, whereby subsidisers' provision of plentiful supplies of cheap energy to citizens is a cornerstone of their citizens' participation in the natural resources wealth of their country.

3.12 Kuwaiti Government Electricity Subsides

The Kuwaiti government bears a heavy financial burden in the form of electricity subsidies for citizens as part of Kuwait's extensive welfare system. In order to measure this burden on the Kuwaiti government nominally it is crucial to determine the price of a KW of electricity. Since 1966, the cost of one KW of electricity generated in Kuwait is 38 fills: the consumers pay 2 fills and the Kuwaiti government pays 36. Table 3.9 presents the subsidy price from 1953 to the present.

Table 3.9: Subsidy price from 1953 to present [149]

Year	kW price in fils*
1953	27
1953-1955	18
1955-1960	13.5
1961-1964	7.5
1964-1965	2
1966 to present	2

* The Kuwaiti dinar (KWD) is made of 1000 fils.

Due to the increase in population as well as urban expansion, the government's financial burden has increased and continues to increase (Figure 3.10). In economic terms, the cost goes far beyond the subsidy; electricity generation in Kuwait is essentially completely dependent on oil, which means that the government is subsidizing cheap oil that could otherwise be profitably exported. The Kuwaiti government loses 10% of the value of its production by using such oil in electricity generation [149]. According to officials in the MEW, the cost of electricity production in Kuwait reached KD 3bn in 2012, while consumers do not pay more than KD 160m annually (due to the aforementioned subsidy).

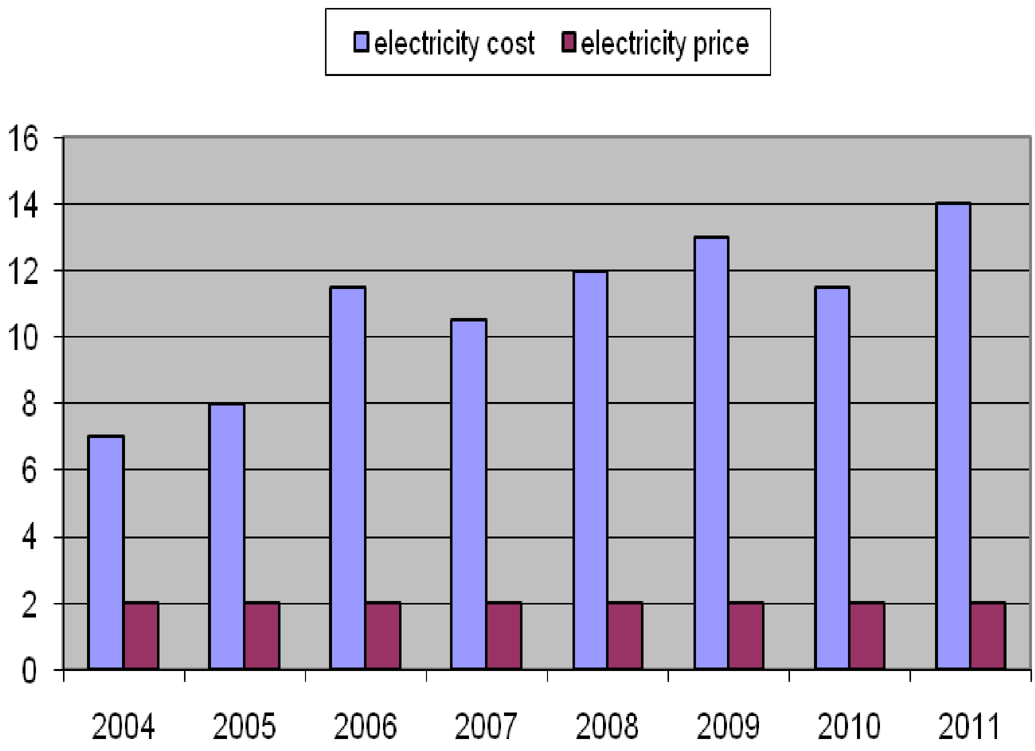

Figure 3.10: Electricity costs and prices in Kuwait [149]

3.13 Cost Components

The increase in cost is attributed to the components used in generating electricity in Kuwait. Based on the report by top officials, electricity is generated through combustion of a mixture of liquidated fuel, more than 70% of which is crude oil and other oil products, and 30% is liquidation gas. This draws 300,000 barrels of oil daily from Kuwait's oil production (about 10% of all national production). Besides, the government is required to import liquidated natural gas every year valued at $1.5-2bn (US) to use in the mixture to generate electricity. From an economic point of view, if Kuwait exported the oil used in generating electricity, it would have obtained over KD 3bn annually. As such, it appears that the situation is getting worse, and that the cost of electricity production will increase.

Based on views of [144], the huge growth in consumption of oil for electricity generation in Kuwait will drain 600,000 barrels per day by 2017 (i.e. about 20% of Kuwait's oil production). This increase in electricity consumption is expected in view of the expansion of housing, new projects, and increasing population. In addition, [150] state that the population of Kuwait is expected to increase to 4.34

million by the end of 2017. What is more, other reports talk about an increase of 5.3% annually in electricity consumption in Kuwait over the coming years.

3.14 Subsidy Comparison of other Gulf Countries and Kuwait

A subsidy comparison of the charges for electricity in different Gulf countries illustrates that charges collected from electricity consumers in Kuwait are the lowest while this is the only country applying a flat rate (fills/kW), regardless of the type and amount of usage. Basically, this is one of the main factors pushing up the cost of electricity production shouldered by the government.

Essentially, other Gulf countries embrace the escalating rate pricing system in electricity charges imposed on users by dividing them into different segments as per their usage level. As regards the charge of residential electricity consumers, in Qatar it is 6 fills/kW for those using less than 4000 kW, rising to 8 fills/kW for those who exceed this limit, whereas in Saudi Arabia the cost is divided into eight segments per the amount of consumption, and ranges from 4 to 20 fills/kW. Conversely, in Oman this cost is divided into five segments, and ranges from 7.5 to 22 fills/kW, whereas in Bahrain the charge of electricity paid by the citizens is divided into three segments pursuant to the amount of usage, and ranges from 2.25 to 12 fills/kW, while there is a fixed rate for expatriates (12 fills/kW) regardless of the amount of usage. Indeed, Dubai has the highest charge of electrical usage among the GCC countries – charges are divided into four segments based on the amount used, and range from 18 to 30 fills/kW.

Table 3.10: Electricity subsidy in GCC countries

Country	*Kilowatt price in fills for residential usage*
Dubia	18-30
Oman	7.5-22
Saudi Arabia	4-20
Qatar	6-8
Bahrain	2.25-12
Kuwait	2

3.15 Kuwait Renewable Energy (Al-Shagaya Project)

Basically, Al-Shagaya project can be considered as Kuwait’s first ambitious attempt to establish a base and securing a foothold in the renewable energy market. It is an important step towards the realization of a GCC state that is free of its dependence on oil as a primary means of energy production. This renewable energy project, as a recap, and as aforementioned, will be developed in phases. While the government will finance the first phase, the second and third phases will be offered to investors on a Build-Operate-Transfer (BOT) basis for 25 years, during which the government pledges to buy all output. Essentially, the project includes 70 MW of different commercially proven technologies, mainly 50 MW parabolic trough technology equipped with Thermal Energy Storage (TES) system, and backed up by fuel boilers of about 10 MW Photovoltaic and 10 MW Wind [151].

3.16 Aim and Objectives of Al-Shagaya Project

In line with R&D [151], the purpose behind the development of Al-Shagaya project is to enable assessment of the performance of different renewable energy technologies employed by Kuwait. These various technologies include PV, CSP, and wind in addition to energy storage with and without co-firing capacities under local climate conditions. Importantly, [152] stated that the target for this project is to enable RES to contribute 15% of Kuwait’s total production by 2030.

3.17 The Variables of Attitude and Knowledge in Relation to RE

3.17.1 Attitudes and RE

Principally, attitude is one of the most important obstacles faced when trying to implement RE; since there is an existing consistency between an individual’s attitude and his or her subsequent behaviour. In essence, the consistent relationship between attitude and behaviour becomes obvious when researchers try to measure attitude as a means of predicting human behaviour. Indeed, attitudes and behaviour variables are complex. Thorough, interdisciplinary understanding ‘is a pre-requisite for any strategy aimed at change’ [153]. [154] agreed that looking for social acceptance of RE innovation is an important factor for successful implementation. Studies show that attitudes are learned and not inherited, and are organized around beliefs, but both beliefs and attitudes are learned. However, Bang et al.’s (2000) study of consumer concerns, knowledge, belief and attitudes toward RE suggested that the consumers’ environmental concerns about RE to-date are more emotionally charged than fact- or knowledge-based [155].

For the definition of 'attitude', this research adopts the description given by a previous study [156]: 'a learned predisposition to respond in a consistently favourable or unfavourable manner toward an object'. Predisposition is inside and unobservable, manifest in a hidden readiness to respond to various situations and issues.

3.17.2 Knowledge and RE

In connection with RE, [50] reiterated the importance of examining public and officials' understanding and knowledge of RE sources as well as its benefits to human health and the environment. Based on the definition of 'knowledge' from reading several studies on RE sources knowledge and understanding, the main issues addressed include the significance of being acquainted with emerging energy technologies, the RE structure and consumption patterns, and the need to be well-informed on energy requirements.

3.18 Attitudes and Knowledge in Relation to RE

Pragmatic studies conducted on attitudes and knowledge about RE, particularly wind and solar energies, have ascertained their significance in relation to public and officials [157]. The main drawbacks with respect to attitudes and knowledge about RE are believed to include lack of awareness about RE sources and the benefits (social, economic, and environmental). Particularly, there is general lack of awareness among the public and officials in relation to wind and solar energy.

Empirical studies that have been carried since RE emerged have been interested in perceptions from individuals and/or groups. In fact, a number of studies [158][159] demonstrated the effects of understanding and awareness as well as public attitudes with regard to decision making and implementation of RE technologies. In particular, these studies have found that the implementation of RE technologies is affected by the assumption of 'public acceptance' [55]. Basically, the US Federal Energy Administration elucidated the barriers of RE acceptance among the public by attributing this to lack of awareness and knowledge [158]. Other studies [160][161] have used quantitative and qualitative methods – also referred to as mixed-method approach – while stating their importance in assisting researchers to get sufficient information instead of utilizing just one of the methods. As regards qualitative data, they provide significant ideas of constructing survey questionnaires, while providing analyses of survey results. As such, they act as a valuable way of establish unquantifiable concepts such as attitudes and knowledge.

[162] illustrated that surveys act as ‘a halfway house on the qualitative continuum…may be qualitative, as when interviews or open-ended questionnaires are used, or quantitative, as when closed-ended or multiple-choice questions are used.’ Equally, [163] illustrated that ‘surveys can be thought of as ‘methods used for descriptive research’ whereas [164] stated the importance of understanding public attitudes and knowledge in which case is provision of vital ways of formulating RE policies by governments.

According to [161], public attitudes, awareness, and understanding are important aspects determining the adoption of RE technologies and implementation of energy policy goals. In this regard, it was established that public attitudes are vital in the extensive comprehension of the dynamics of public views with respect to RE technologies.

Similarly, [157] analyzed and evaluated the Croatian assessment of environmental attitudes, knowledge and attitudes about RE and RE sources as well as energy efficiency. The findings indicated that while Croatia has considerable possibilities for energy production from renewable resources, they are hindered by certain social barriers. These barriers include lack of knowledge and information, long-term process of behaviour change, misunderstanding of real natural RE, and a general lack of interest and desire as well as lack of financial resources as a result of power and influence.

[160] analyzed public knowledge, beliefs, and attitudes demonstrated towards alternative sources of energy and their acceptance in Australia. In this regard, the findings indicated that variables of being younger, possessing higher knowledge levels, pro-environmental beliefs, and positive attitudes prompt the general public into embracing the distribution of RET. Equally, the findings illustrated utilities distributed generation features, which include, cost to installation, ease of installation, ease of use, reduction in carbon emissions, potential exhaust fumes, the

generator’s energy source, reliability and durability, safety levels, and savings in due course.

[164] investigated the manner in which public environmental perceptions are shaped by cultural and ideological identities as well as how deliberation of these perceptions might help to influence the government policy as regards the development of RE in southwest Britain. In this connection, the findings focused on public reluctance to invest in RE as the main obstacle while outlining ways in which government policies on RE might be customized to motivate public support and participations.

[165] conducted a study on cultural pitfalls with respect to RE and energy efficiency in the US by utilizing formal semi-structured interviews with 181 participants at 82 institutions. Astonishingly, he found that American attitudes toward RE are determined by social dimensions and values such as consumption, trust, control, abundance, and freedom. Consequently, participants rejected RE technologies, especially wind farms and solar panels, ‘simply [because] they do not comprehend why such technologies may be needed’ [165]. Conversely, [166] studied stakeholders’ perceptions and understanding of wind-generated electricity to meet a significant portion of increased electricity demands in Saskatchewan, Canada. In their study, they found that the most significant barriers stakeholders hold are technological and political barriers, whereas most members of the public are aware of these barriers.

3.19 Summary of the Review of the Literature

Essentially, GCC countries are strongly defined by their abundant hydrocarbon wealth; however, they rank among the top 25 of the world’s biggest per capita carbon dioxide emitting countries. Due to the GCC’s obligation to the world, as well as their growing awareness of the negative effects of climate change, these countries have been taking positive steps locally and internationally towards environmental sustainability. Moreover, the GCC countries are starting to position themselves as key players in the development of RETs, supported by large-scale projects such as Masder City in Abu Dhabi. As such, they are leading the way with ideal geography and natural resources to support the transition to alternative energy sources.

The GCC adoption of RE technologies as a substitute for fossil fuels faces many challenges, the most important of which is the lack of a coherent strategy with clear vision. Additional barriers include cost, lack of awareness, and some negative environmental impacts of RETs. In spite of these challenges, the GCC has started to develop environmentally friendly technology projects using wind and solar sources, such as the RE project between Saudi Arabia and the US, Germany, KISR and the MEDRC. Results include a number of solar cooling systems that were successfully installed, and Masder City in Abu Dhabi. This trend needs to be adopted throughout the GCC.

[167] presented the Union of Concerned Scientists report regarding the barriers that preventing RE project from development. The Union categorizes the failure to market the value and benefits of RE as: 1-Commercialization barriers such as underdevelopment infrastructures, lack of economies of scale, and unequal government subsidies and taxes; 2- Market barriers such as lack of RE information and policy; and 3- Institutional barriers such as small size business, high transaction and financing costs, split incentives, energy transaction costs and green market restrictions.

CHAPTER 4: METHODOLOGY

4.1 Theoretical Rationale

In this research a quantitative method on three groups of participants (public, officials and academics) was used to obtain the ‘binocular vision’ described by [168] to gather factual information about the participants to establish a baseline on Kuwaiti attitudes towards and knowledge of renewable energy for purpose of evaluation and to provide results and recommendations to Kuwaiti government. The nature of RE and its many participants makes it suited to ‘inter-disciplinary research using innovative quantitative method with a greater emphasis upon the symbolic, affective and socially-constructed nature of attitudes and knowledge about RETs’ [161]. As [169] observed, there is a need to study RE from ‘different scientific disciplines and theoretical perspectives, in order to develop a more structured understanding of how people feel and understand RE’. In addition, a cost analysis was carried out to investigate the cost of energy generated by MEW in Kuwait using oil and gas, and the energy generated by Al-Shagaya Project until 2030. Moreover, the amount of CO_2 emissions generated by the traditional energy and the CO_2 reduction due to the Al-Shagaya Project are calculated for the same period.

4.2 Purpose of the Study

To achieve above-mentioned aims, the study is fourfold and utilizes the following methods:

1. A questionnaire designed by the author to investigate the attitudes and knowledge about RE of Kuwaiti members of the public, officials and academics. Factors that may have contributed to these attitudes and knowledge and how participants’ attitudes and knowledge influence their actions toward RE are also considered.

2. A cost analysis was carried out to predict the future cost for traditional energy compared to the predicted RE cost until 2030. Moreover, the equation was used to estimation how much CO_2 emission will be generated from traditional energy, and how much CO_2 will be reduced because of using RE.

3. A model was developed to establish a road map for RE project in the GCC possibilities and limitations that tested two arguments the renewable energy feasibility in the GCC countries and its existing berries, and Al-Shagaya Project and its economics and environmental benefits to Kuwait.

4. Recommendations were made for decision makers regarding future RE legislation and activities and recommendations for future research.

4.3 Questionnaire Participants and Data Collection

4.3.1 Participants

The aim of the questionnaire was to target three groups in Kuwait: public, academics and officials, seeking to investigate the attitudes and knowledge of 402 participants. These groups are: 1) the public (Kuwaiti citizens and non-citizen households); 2) the academic faculties in two public institutions (Kuwait University's Petroleum Engineering and Environment Department and the PAAET Electricity and Environment & Health Colleges); 3) officials, or people in charge of renewable energy projects, in the Kuwait Institution for Scientific Research, KOC, the Environment Public Authority and the MEW.

Questionnaire participants and data collection concerned the following:

1. The questionnaire related with 'renewable energy' to investigate the attitudes and knowledge of 'general public' was designed and circulated to 150 people. Out of 150 questionnaires only 110 questionnaires were retained by the author. Out of 110 questionnaires, only 100 were chosen for the data analysis and 10 questionnaires were rejected due to being incompletely filled.

2. The questionnaire related with 'renewable energy' to investigate the attitudes and knowledge of 'academics' was designed and circulated to 135 academic staff. Out of 135 questionnaires, 120 questionnaires were retained by the author. Out of 120 questionnaires, 113 were chosen for the data analysis and 7 questionnaires were rejected, as a lot of columns were not filled by the participants.

3. The questionnaire related with 'renewable energy' to investigate the attitudes and knowledge of 'officials' was designed and circulated to 117 people. All the questionnaires were retained and fully completed.

4.3.2 Data Collection

Two different sources of evidence were used for data collection: data collected from the RE questionnaire *Possibilities and Obstacles for Public, Academic, and Officials* (see Appendix 1), developed by the researcher; and cost analysis of energy and CO_2 emissions.

4.4 Questionnaire

In the process of developing the questionnaire for the study, I relied on the findings and recommendations of researchers in the instrument construction field. [170] stressed that in order to obtain a valid and reliable questionnaire, researchers should seek an instrument that 'measures what [they] want to measure'. Changes on the final version of the instruments were made based on the suggestions received by academics and experts in the field of management and renewable energy to help obtain a valid and reliable questionnaire.

All questionnaires included three categories. The first category asked for demographic information. Requesting personal and academic information from the participants provided an understanding of each participant's background and experience, as well as their age and their approach. The second category explored participants' understanding and general knowledge with regard to RE. The third category served to determine the attitudes of Kuwaitis toward RE. The descriptors were based on a five-point Likert scale:

(1) Strongly Disagree
(2) Disagree
(3) Undecided
(4) Agree
(5) Strongly Agree

The three questionnaires are described in terms of their particular characteristics below:

The Public Possibilities and Obstacles Questionnaire comprised a total of 25 items, nine of which concerned public demographic and background information, nine of which served to determine public attitudes toward RE, and seven of which addressed public awareness and knowledge of RE and its barriers. The research hypotheses for the public were that:

1. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall awareness of own knowledge of renewable energy.
3. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall attitude to renewable energy.
4. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall awareness of own knowledge of renewable energy.
5. There is no statistically significant difference at (.05) with respect to ‘Education’ on overall attitude to renewable energy.
6. There is no statistically significant difference at (.05) with respect to ‘Education’ on overall awareness of own knowledge of renewable energy.

The Academic Possibilities and Obstacles Questionnaire had a total of 41 items, twelve of which asked for academics’ demographic and background information, eight of which served to determine academics’ attitudes toward RE, and 21 of which addressed academics’ awareness of their own knowledge of the RE and its barriers. The research hypotheses for the academics were that:

1. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall awareness of own knowledge of renewable energy.
3. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall attitude to renewable energy.

4. There is no statistically significant difference at (.05) with respect to 'Age' on overall awareness of own knowledge of renewable energy.
5. There is no statistically significant difference at (.05) with respect to 'Education' on overall attitude to renewable energy.
6. There is no statistically significant difference at (.05) with respect to 'Education' on overall awareness of own knowledge of renewable energy.
7. There is no statistically significant difference at (.05) with respect to 'Country of Study' on overall attitude to renewable energy.
8. There is no statistically significant difference at (.05) with respect to 'Country of Study' on overall awareness of own knowledge of renewable energy.

Third: *The Official Possibilities and Obstacles Questionnaire* had a total of 31 items, thirteen of which items asked for officials' demographics and background information, five of which served to determine officials' attitudes toward RE, and thirteen of which addressed officials'' awareness of their own knowledge of the RE and its barriers. The research hypotheses for the officials were that:

1. There is no statistically significant difference at (.05) with respect to 'Gender' on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to 'Gender' on overall awareness of own knowledge of renewable energy.
3. There is no statistically significant difference at (.05) with respect to 'Age' on overall attitude to renewable energy.
4. There is no statistically significant difference at (.05) with respect to 'Age' on overall awareness of own knowledge of renewable energy.
5. There is no statistically significant difference at (.05) with respect to 'Occupation' on overall attitude to renewable energy.
6. There is no statistically significant difference at (.05) with respect to 'Occupation' on overall awareness of own knowledge of renewable energy.

4.5 Cost Analysis

Investigating the projected cost of energy generated by MEW in Kuwait until 2030 compared to cost of energy generated by RE for the same period. Moreover, an estimation of the amount of CO_2 emissions released from traditional energy until 2030 and the amount of CO_2 that will be reduced as a result of using RE for the same period was projected. In order to perform these investigations the researcher applied the following tasks:

1. Traditional Energy Generation by MEW using MATLAB programming tool:
   a. To help predict the amount and cost of energy that will be generated by MEW until 2030;
   b. To predict the future amount of CO_2 emissions released until 2030.
2. Giving the amount of renewable energy generated by the Al-Shagaya Project:
   a. To predict the cost of the RE energy generated by Al-Shagaya Project until 2030.
   b. To estimate the amount of CO_2 emission reduction due to RE.

4.6 Translation Procedures and Administering the Questionnaires

The following steps were employed in translating and conducting the questionnaires:

1. A professional translation firm translated the questionnaire from English into Arabic.
2. The Arabic version of the questionnaires were attached to the English version, and then sent to the English Department of Kuwait University. The questionnaires were then checked through a literal comparison between both the original English version of the questionnaires with the Arabic translation. This was done by Kuwaiti professors of linguistics, which helped to identify any items in the Arabic version that might need revision.
3. Recommendations of these experts were used to modify (or eliminate) any items deemed to require this.
4. The questionnaires were accompanied by a covering letter to help participants understand the purpose of the research and to assure them of the confidentiality of their answers.
5. To ensure anonymity of participants no names were required and all questionnaires were placed in an envelope.

CHAPTER 5: DATA ANALYSIS OF THE QUESTIONNAIRES

5.1 Public

5.1.1 Background on RE

The public participants (n=100; 100%), comprised 45% women and 55% men, of whom 70% had a postgraduate qualification and 30% had a graduate or lower qualification. Half (50%) were in the age group of 'up to 37 years old', while the other half were in the age group of 'more than 37 years old'.

The results of the public background information are shown in Table 5.1 and Figure 5.1. The results show that all public participants (100%) feel that they are environmentally conscious and the majority of them are satisfied with the electricity price that government of Kuwait has fixed. They also very strongly support government subsidy of electricity to all the people and the private sector in Kuwait. However, 98% would support decreasing government electricity subsidy in order to promote RE, clearly showing that the vast majority of people of Kuwait are in favour of serious government action on RE. Public opinions were taken regarding the question related with the benefits of using the renewable energy sources to generate electricity. Participants were asked to mention various benefits that they feel about the renewable energy sources (Table 5.2).

Table 5.1: Public background information on RE

Variables	Yes No. (%)	No No. (%)
Do you think that you are environmentally conscious?	100 (100)	0 (0)
Are you satisfied with the electricity price in Kuwait?	84 (84)	16 (16)
Do you support the Kuwaiti government subsidizing electricity?	97 (97)	3 (3)
Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?	86 (86)	14 (14)
Would you support decreasing government electricity subsidy in order to promote renewable energy?	98 (98)	2 (2)

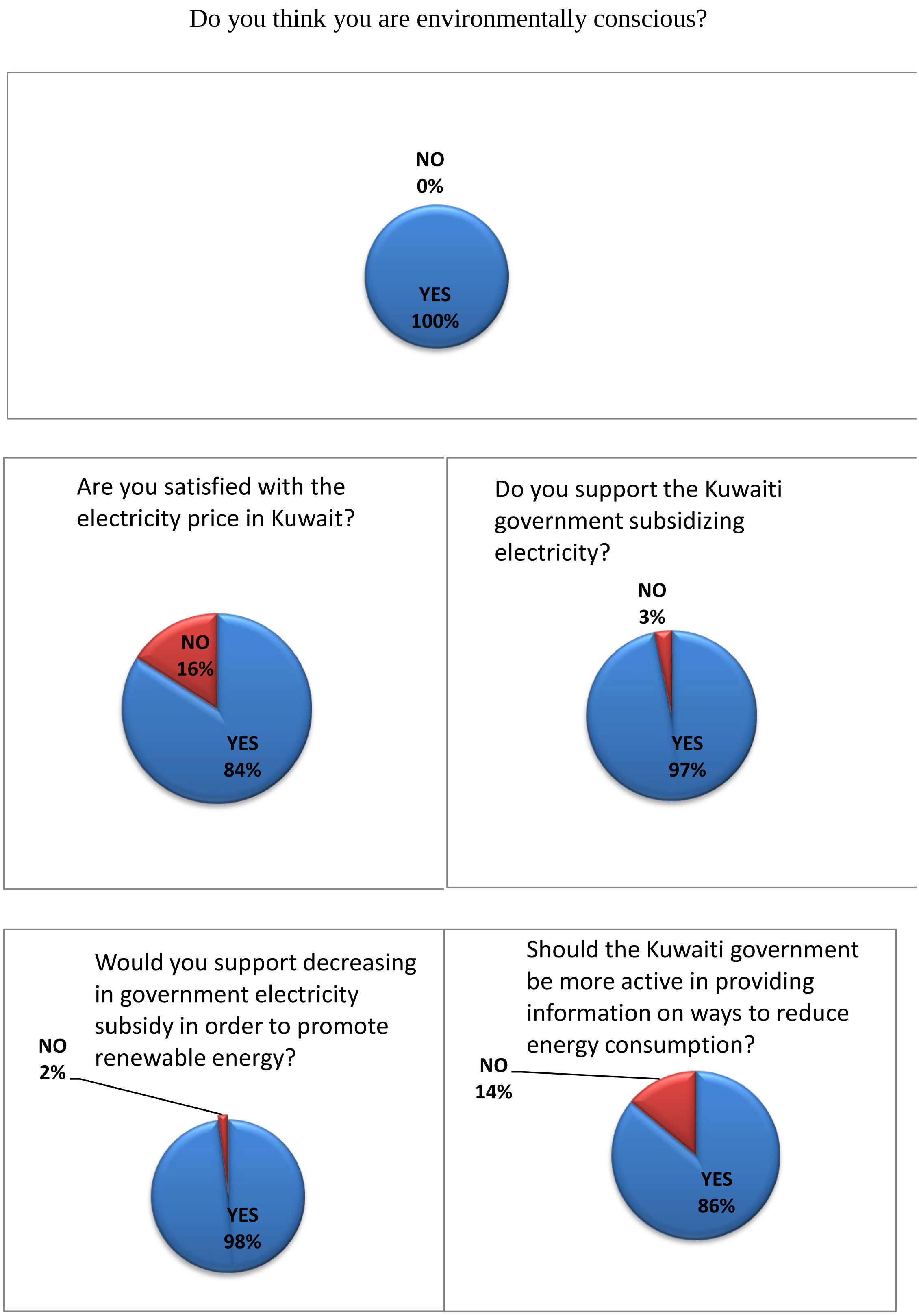

Figure 5.1: Public opinion on energy issues

Table 5.2: Public opinion on RE

Variables (perceived benefits of RE)	*Yes* *No. (%)*	*No* *No. (%)*
Lower energy bills	65 (65)	35 (35)
Good for environment	98 (98)	2 (2)
Less reliance on electric oil and natural gas	84 (84)	16 (16)
There will not be a need for investment in nuclear power plant	35 (35)	65 (65)
Good for economy	84 (84)	16 (16)
There is no benefit	1 (1)	99 (99)

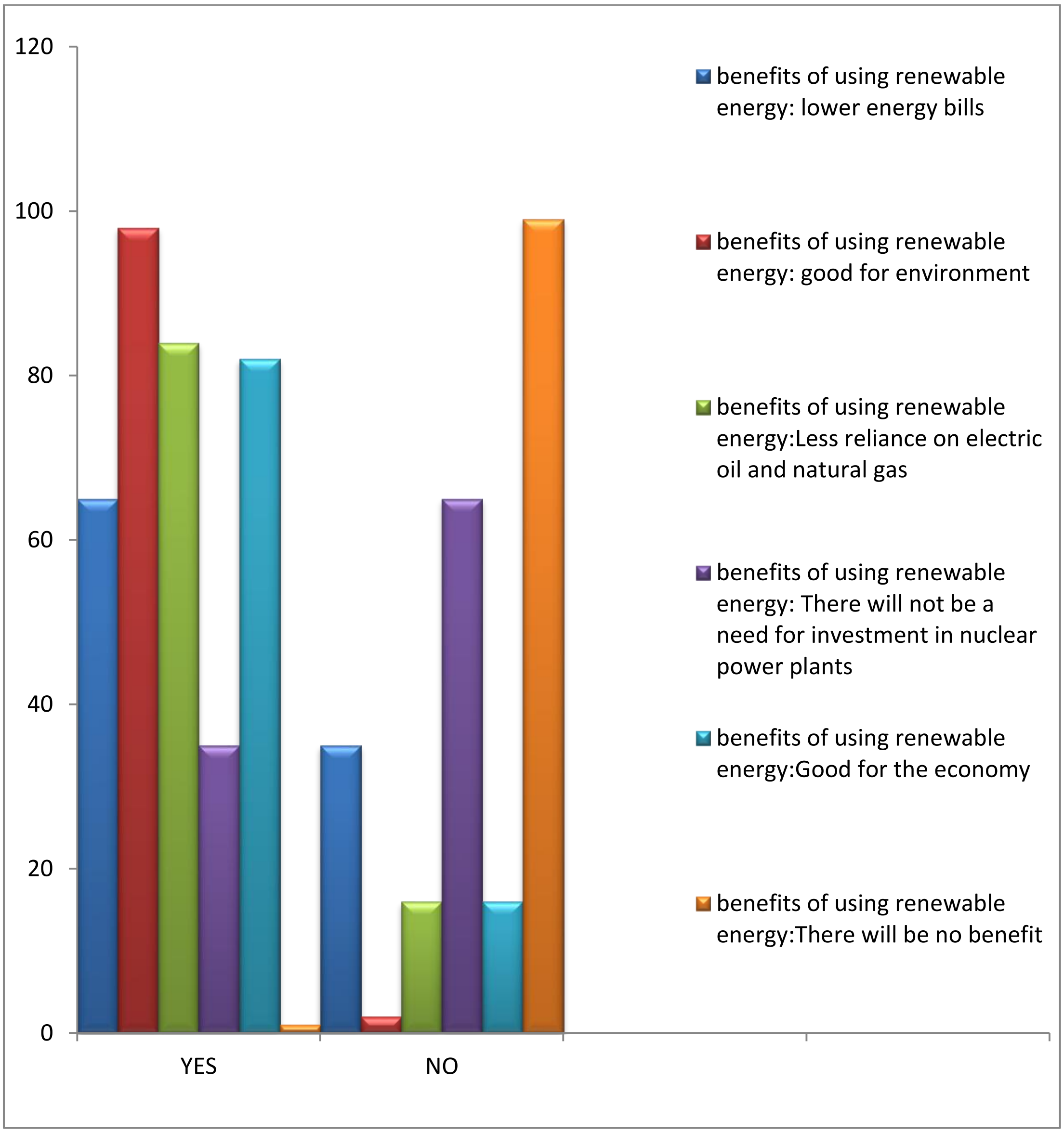

Figure 5.2: Benefits of using RE

5.1.2 Attitudes toward Renewable Energy

Public opinion held that the greatest benefit of RE was that it was good for the environment (98%), followed by its reduction of dependence on oil and natural gas

(84%). 84% of people feel that renewable energy will also be good for the economy. A total of nine items were designed to see the attitude of public regarding the issue of renewable energy. All the results are shown in Table 5.3 in the descending order of their mean values.

Mean values shows that public regard the use of renewable energy as highly important, and they think there is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere. The third highest mean value shows that people feel that using RES is important for the future of Kuwait. Percentage wise distribution of respondents' opinions expressed in five-point Likert scale concerning all questions related with 'Attitude towards Renewable Energy' and frequency distribution (%) of all variables are shown in the Tables 5.3-5.4.

The answer to Q11 shows that all 100% of respondents support the use of the renewable energy. The answer to Q12 shows that only 1% of respondents say that 'All renewable energy sources are unattractive to me; The answer to Q13 shows that 100% of respondents say that 'There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere'. The answer to Q14 shows that only 52% of respondents support the idea that 'With the existing traditional fuels sources; the Kuwaiti government should not waste time investing in renewable energy technologies'. The answer to Q15 shows that all the 100% of respondents support 'the building of 'clean' renewable energy facilities to generate electricity in my local area'. The answer to Q16 shows that only 55% feel that 'Individual households should support the cost of using renewable energy sources'. The answer to Q17 shows that about 98% of respondents support the government's policy of generating Kuwait electricity needs from renewable energy'. The answer to Q18 shows that only 36% of respondents feel that 'Renewable energy technologies sites should not be located in their living area'. The answer to Q19 shows that all the 100% of respondents feel that 'Using renewable energy sources are ways of looking after our future in Kuwait'.

Table 5.3: Mean and SD of public opinion 'Attitude towards Renewable Energy'

	Variables	*Mean*	*SD*
Q11	I support the use of renewable energy	4.80	.402
Q13	There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere	4.79	.409
Q19	Using renewable energy sources are ways of looking after our future in Kuwait	4.73	.446
Q15	I support the building of 'clean' renewable energy facilities to generate electricity in my local area	4.52	.502
Q17	I support the government's policy of generating our electricity needs from renewable energy	4.43	.624
Q16	Individual households should support the cost of using renewable energy sources	3.79	.891
Q14	With the existing traditional fuels sources running out, the Kuwaiti government should not waste time investing in renewable energy technologies	3.18	1.666
Q18	Renewable energy technologies sites should not be located in my living area	2.75	1.466
Q12	All renewable energy sources are unattractive to me	1.56	.574

Table 5.4: Percentage wise distribution of public opinion on 'Attitude towards Renewable Energy' Scale

Q	*Variables*	*Likert responses (%)*				
		Strongly Disagree	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
11	I support the use of renewable energy	.0	.0	.0	20.0	80.0
12	All renewable energy sources are unattractive to me	47.0	51.0	1.0	1.0	.0
13	There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere	.0	.0	.0	21.0	79.0
14	With the existing traditional fuels sources running out, the Kuwaiti government should not waste time investing in renewable energy technologies	32.0	2.0	14.0	20.0	32.0
15	I support the building of 'clean' renewable energy facilities to generate electricity in my local area	.0	.0	.0	48.0	52.0
16	Individual households should support the cost of using renewable energy sources	1.0	1.0	43.0	28.0	27.0
17	I support the government's policy of generating our electricity needs from renewable energy	1.0	.0	1.0	51.0	47.0
18	Renewable energy technologies sites should not be located in my living area	33.0	9.0	22.0	22.0	14.0
19	Using renewable energy sources are ways of looking after our future in Kuwait	.0	.0	.0	27.0	73.0

5.1.3 Awareness of Own Knowledge of RE and its Barriers

Opinions regarding ‘awareness of own knowledge’ towards ‘renewable energy’ was taken. A total of seven items were designed as shown in Table 5.5**.**

Table 5.5: Mean and standard deviation of all the items related with ‘Awareness of Own Knowledge of Renewable Energy and its Barriers’

Q	*Variables*	*Mean*	*SD*
21	Reducing my household’s energy consumption would help protect the environment	4.65	.500
26	Most of the air pollution in Kuwait is caused by production and use of oil and gas	4.59	.726
25	Renewable energy sources are environmentally sustainable	4.56	.556
24	In the future, we will no longer be able to use fossil fuels to generate electricity	4.29	.935
20	I am well informed about renewable energy sources (solar, wind, hydroelectric)	3.72	1.102
23	Renewable energy technologies have environmental problems such as noise and visual intrusion	2.13	1.041
22	Renewable energy technology causes environmental damages and pollution	1.94	1.127

Mean values (Mean=4.65, SD=0.5) show that people attach the highest importance to decreasing the use of household energy consumption as it will protect the environment. The second highest mean value (Mean=4.59, SD=0.726) shows that public feel that most of the air pollution in Kuwait is caused by the production and use of oil and gas. The third highest mean value (Mean=4.56, SD=0.556) shows that people feel that renewable energy sources are environmentally sustainable. Percentage wise distribution of respondents’ opinions on all the questions related with ‘Awareness of Own Knowledge of Renewable Energy and its Barriers’ Scale is expounded below, and shown in Table 5.6.

Answers to Q20 show that only 56% of respondents agree that they are ‘well informed about renewable energy sources (solar, wind, hydroelectric)’.

Answers to Q21 show that 99% of respondents feel that ‘Reducing their household’s energy consumption would help protect the environment’.

Answers to Q22 show that 70% of respondents disagree and only 15% agree that ‘Renewable energy technology causes environmental damages and pollution’.

Answers to Q23 show that 67% of respondents disagree and 14% agree that 'Renewable energy technologies have environmental problems such as noise and visual intrusion'.

Answers to Q24 show that about 76% of respondents agree that 'In the future, we will no longer be able to use fossil fuels to generate electricity'.

Answers to Q25 show that 97% of respondents feel that 'Renewable energy sources are environmentally sustainable'.

Answers to Q26 show that about 86% of respondents agree that 'Most of the air pollution in Kuwait is caused by production and use of oil and gas'.

Table 5.6: Percentage wise distribution of respondents 'Awareness of Own Knowledge of Renewable Energy and its Barriers'

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
20	I am well informed about renewable energy sources (solar, wind, hydroelectric)	.0	17.0	27.0	23.0	33.0
21	Reducing my household's energy consumption would help protect the environment	.0	.0	1.0	33.0	66.0
22	Renewable energy technology causes environmental damages and pollution	51.0	19.0	15.0	15.0	.0
23	Renewable energy technologies have environmental problems such as noise and visual intrusion	34.0	33.0	19.0	14.0	.0
24	In the future, we will no longer be able to use fossil fuels to generate electricity	1.0	2.0	21.0	19.0	57.0
25	Renewable energy sources are environmentally sustainable	.0	.0	3.0	38.0	59.0
26	Most of the air pollution in Kuwait is caused by production and use of oil and gas	.0	.0	14.0	13.0	73.0

5.1.4 Reliability

Reliability of all the items regarding their attitude and awareness knowledge was measured by applying SPSS Procedure 'Reliability Analysis using the Cronbach's Alpha'. The reliability of all the items regarding with their attitudes was achieved 0.637 and this shows that a level of high internal consistency among all the items related with attitude scale.

The reliability of all the items regarding their awareness knowledge was achieved 0.777 and this again shows that a level of high internal consistency among all the items related with awareness knowledge scale.

5.1.5 Pearson Correlation Coefficient and T-test

Pearson Correlation Coefficient was computed between 'Overall Attitude towards Renewable Energy' Scale and 'Overall Awareness of Own Knowledge of Renewable Energy and its Barriers' Scale and it was found that the correlation between them was very strong, positive and statistically significant at (0.001), $r(98)=0.729$, $p < 0.001$.

5.1.6 Creating Overall Attitude & Overall Awareness Knowledge Variables

All the negative items were recoded to convert them to positive items. Two new variables 'overall attitude' and 'overall awareness knowledge' were created by adding and dividing by number of variables related with their respect scales.

Overall mean attitude of all the 100 participants regarding the renewable energy was 4.21 out of 5 and overall mean value of their 'awareness knowledge' regarding the renewable energy was 4.2486. This shows that overall people were in favour of renewable energy.

T-test was applied with respect to 'gender', 'age' and 'education' on these two newly created 'overall attitude to renewable energy' and 'overall awareness knowledge of renewable energy' variables. The results are described below.

5.1.7 T-Test with respect to Gender

The following two research hypotheses are tested with respect to gender.

1. There is no statistically significant difference at (.05) with respect to 'Gender' on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to 'Gender' on overall awareness of own knowledge of renewable energy.

T-Test with respect to gender (female, male) was applied on 'overall attitude to renewable energy'. Table 5.7 shows that there is a statistically significant difference at (.001) with respect to Gender on overall attitude to renewable energy, t (98)=-8.418, $p \leq 0.001$ (p=0.000). The mean values of 'overall attitude to renewable energy' shows that male participants (M=4.48, SD=0.371) have higher attitude about the renewal energy than female participants (M=3.89, SD=0.316).

Table 5.7: T-Test with respect to Gender on 'Overall attitude to renewable Energy' &'Overall Awareness Knowledge of Renewable Energy'

Variables	*Gender*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	*η^2*
Overall attitude to RE	F	45	3.89	.316	-8.418	98	0.000***	.42
	M	55	4.48	.371				
Overall awareness knowledge of RE	F	45	3.91	.443	-6.269	97.987	0.000***	.279
	M	55	4.52	.536				

*** $p \leq 0.001$; $\eta^2 \rightarrow$ Partial Eta Squared

The strength of relationship between 'gender' variable and 'overall attitude to renewable energy', as assessed by η^2 (Partial Eta Squared), was very strong, with gender variable accounting for 42% of the variance of the 'overall attitude' variable.

T-Test with respect to gender (female, male) was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.7 shows that there is a statistically significant difference at (.001) with respect to 'Gender' on overall awareness of own knowledge of renewable energy, t (97.987)=-6.269, $p \leq 0.001$ (p=0.00 0). The mean values of 'overall awareness of own knowledge of renewable energy' shows that male participants (M=4.52, SD=0.536) have much higher awareness of knowledge about the renewable energy than female participants (M=3.91, SD=0.443).

The strength of relationship between 'gender' variable and 'overall awareness of own knowledge of renewable energy', as assessed by η^2 (Partial Eta Squared), was nearly strong, with gender variable accounting for 28.0% of the variance of the 'overall awareness of own knowledge of renewable energy' variable.

5.1.8 T-Test with respect to Age

The following two research hypotheses were tested with respect to age.

1. There is no statistically significant difference at (.05) with respect to 'Age' on overall attitude to renewable energy.

2. There is no statistically significant difference at (.05) with respect to 'Age' on overall awareness of own knowledge of renewable energy.

T-Test with respect to age (up to 37, 37 and over) was applied on 'overall attitude to renewable energy'. Table 5.8 shows that there is a statistically significant difference at (.001) with respect to Age on overall attitude to renewable energy, t (83.474)=-3.666, $p \leq 0.001$ (p=0.000). The mean values of 'overall attitude to renewable energy' show that participants aged over 37 have much higher awareness of renewable energy (M=4.37, SD=0.509) than participants aged under 37 (M=4.06, SD=0.326).

The strength of relationship between 'age' variable and 'overall attitude to renewable energy', as assessed by η^2 (Partial Eta Squared), was very strong, with age variable accounting for 12.1% of the variance of the 'overall attitude' variable.

T-Test with respect to age was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.8 shows that there is a statistically significant difference at (.005) with respect to Age on overall awareness of own knowledge of renewable energy, t (67.948)=-3.072, $p \leq 0.01$ (p=0.003). The mean values of 'overall awareness of own knowledge of renewable energy' show that participants aged over 37 have much higher awareness and knowledge about renewable energy (M=4.42, SD=0.72) than participants aged under 37 (M=4.08, SD=0.323).

The strength of relationship between 'age' variable and 'overall awareness of own knowledge of renewable energy' as assessed by η^2 (Partial Eta Squared) was nearly strong, with age variable accounting for 9% of the variance of the 'overall awareness of own knowledge of renewable energy' variable.

Table 5.8: T-Test with respect to Age on 'Overall attitude to renewable Energy '&'Overall Awareness Knowledge of Renewable Energy'

Variables	*Age*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	*η^2*
Overall attitude to renewable energy	Up to 37	50	4.06	.326	-3.666	83.474	0.000***	.121
	More than 37	50	4.37	.509				
Overall awareness knowledge of renewable energy	Up to 37	50	4.08	.323	-3.072	67.948	0.003**	.089
	More than 37	50	4.42	.720				

*** $p \leq 0.001$; ** $p \leq 0.005$; η^2→ Partial Eta Squared

5.1.9 T-Test with respect to Education

The following two research hypotheses were tested with respect to education:

1. There is no statistically significant difference at (.05) with respect to 'Education' on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to 'Education' on overall awareness of own knowledge of renewable energy.

T-Test with respect to education (Master's or more, Bachelor's or less) was applied on 'overall attitude to renewable energy'. Table 5.9 shows that there is no statistically significant difference at (.05) with respect to 'Education' on overall attitude to renewable energy, t (86.703)=.637, $p > 0.05$ (p=0.526). The mean values of 'overall attitude to renewable energy' show that participants with postgraduate qualifications have much higher attitude about renewable energy (M=4.23, SD=0.505) than those qualified to graduate level or less (M=4.18, SD=0.305).

T-Test with respect to education was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.9 shows that there is a statistically significant difference at (.005) with respect to 'Education' on overall awareness of own knowledge of renewable energy, t (97.946)=2.988, $p \leq 0.005$ (p=0.004). The mean values of 'overall awareness of own knowledge of renewable energy' show that participants, who had an education as 'Master's or more', have much higher awareness knowledge about the renewable energy (M=4.33, SD=0.653) than the participants who had an education as 'Bachelor's or less' (M=4.05, SD=0.284).

The strength of relationship between 'education' variable and 'overall awareness of own knowledge of renewable energy', as assessed by η^2 (Partial Eta Squared), was almost near medium, with education variable accounting for 5% of the variance of the 'overall awareness of own knowledge of renewable energy' variable.

Table 5.9: T-Test with respect to Education on 'Overall attitude to renewable Energy '&'Overall Awareness Knowledge of Renewable Energy'

Variables	*Education*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	η^2
Overall attitude to renewable energy	Master or more	70	4.23	.505	.637	86.703	.526	.003
	Bachelor or less	30	4.18	.305				
Overall awareness knowledge of renewable energy	Master or more	70	4.33	.653	2.988	97.946	.004**	.049
	Bachelor or less	30	4.05	.284				

** $p \leq 0.005$; $\eta^2 \rightarrow$ Partial Eta Squared

5.2 Academics

5.2.1 Background on Renewable Energy

The academic participants (n=113) comprised 61 (54%) women and 52 (46%) men. 89 (78.8%) participants PhD qualifications whereas 24 (21.2%) participants had Master's-level qualifications. 25 (22.1%) participants studied in Kuwait, 39 (34.5%) studied in Europe and 49 (43.4%) studied in North America. 47 (41.6%) participants were 'up to 47 years old' and 66 (58.4%) participants were 'more than 47 years old' (Table 5.10).

The results show that all the 83.2% of academic participants feel that they are environmentally conscious, and 84.1% are satisfied with the electricity prices that the government of Kuwait has fixed. 82.3% support electricity subsidies. 81.4% feel that the Kuwaiti government should be more active in providing information on ways to reduce the energy consumption. Interestingly, 61.9% of participants support decreasing government electricity subsidy in order to promote renewable energy. This shows that the majority of academics in Kuwait are in favour of renewable energy, but to a lesser extent than the general public (Table 5.10, Figure 5.3).

Academics' opinions were taken regarding the question related with the benefits of using the renewable energy sources to generate electricity. Academics were asked to mention various benefits that they feel about the renewable energy sources. The results are shown in Table 5.10, Figure 5.3.

The highest academics' opinions about the benefits of renewable energy are related to 'environment' (78.8%) then to 'less dependency on electric oil and natural gas' (57.5%). 47.8% feel that renewable energy will also be 'good for economy' and only 38.1% feel that it will help in 'lowering the energy bill'.

About 57 (50.4%) participants feel that Kuwait is ready to switch to RE in future. The participants' multiple opinions were taken regarding the kind of RE they intend to use in future. The highest participant support was for 'solar energy' (46.9%), followed by 29.2% supporting 'wind energy', and only 11.5% supported 'biomass energy'.

About 54.9% participants feel that it is easy to start using renewable energy technologies to generate energy in Kuwait whereas 45.1% feel that it is difficult to start using renewable energy technologies to generate energy in Kuwait.

Table 5.10: Academics' opinions on RE

Variables	*Yes* *No. (%)*	*No* *No. (%)*
Do you think that you are environmentally conscious?	94 (83.2)	19 (16.8)
Are you satisfied with the electricity price in Kuwait?	95 (84.1)	18 (15.9)
Do you support the Kuwaiti government subsidizing electricity?	93 (82.3)	20 (17.7)
Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?	92 (81.4)	21 (18.6)
Would you support decreasing government electricity subsidy in order to promote renewable energy?	70 (61.9)	43 (38.1)

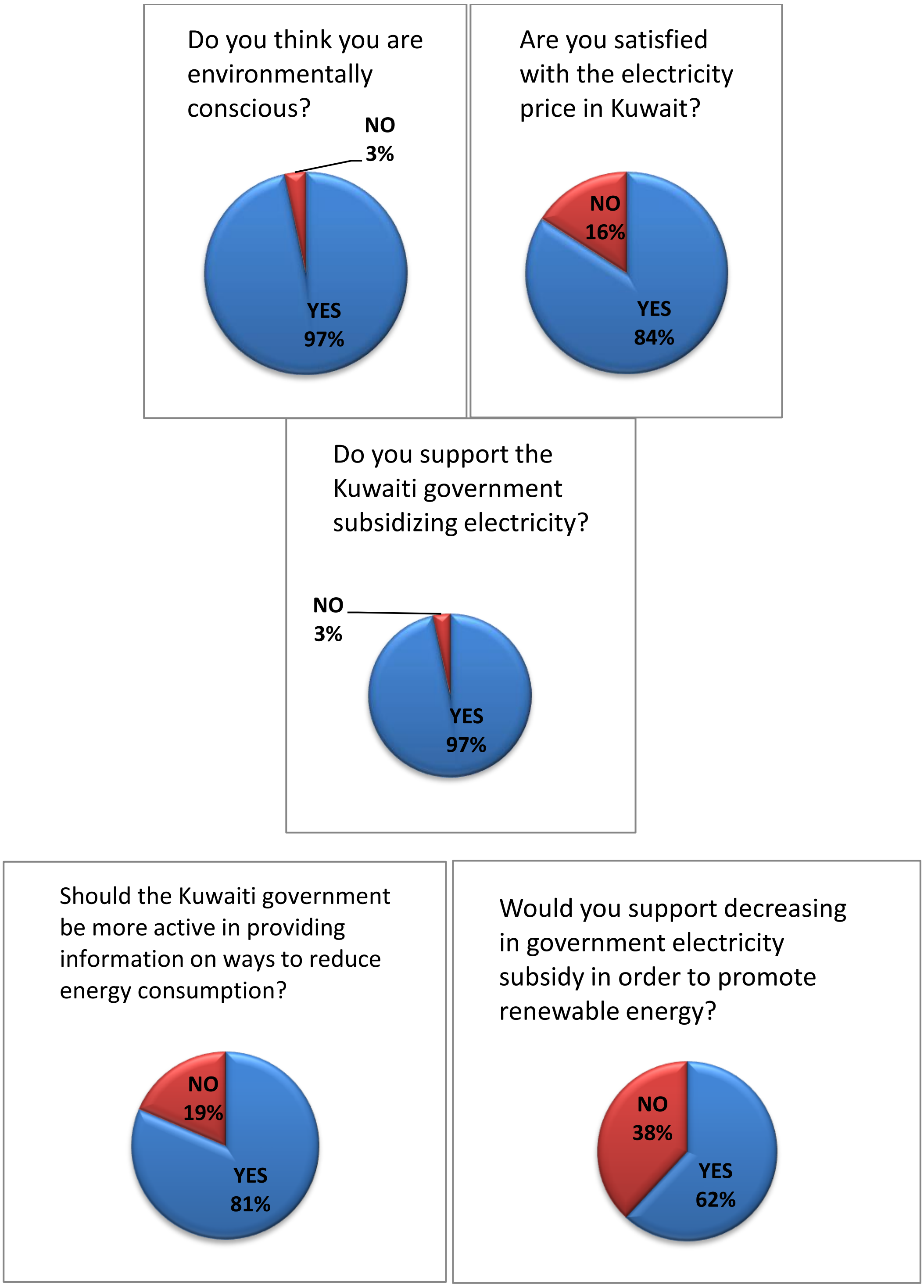

Figure 5.3: Academics' opinions on RE

Table 5.11: Benefits of Using RE (academics)

Variables (perceived benefits of using RE)	*Yes No. (%)*	*No No. (%)*
Lower energy bills	43 (38.1)	70 (61.9)
Good for environment	89 (78.8)	24 (21.2)
Less reliance on electric oil and natural gas	65 (57.5)	48 (42.5)
There will not be a need for investment in nuclear power plant	18 (15.9)	95 (84.1)
Good for economy	54 (47.8)	59 (52.2)
There is no benefit	4 (3.5)	109 (96.5)

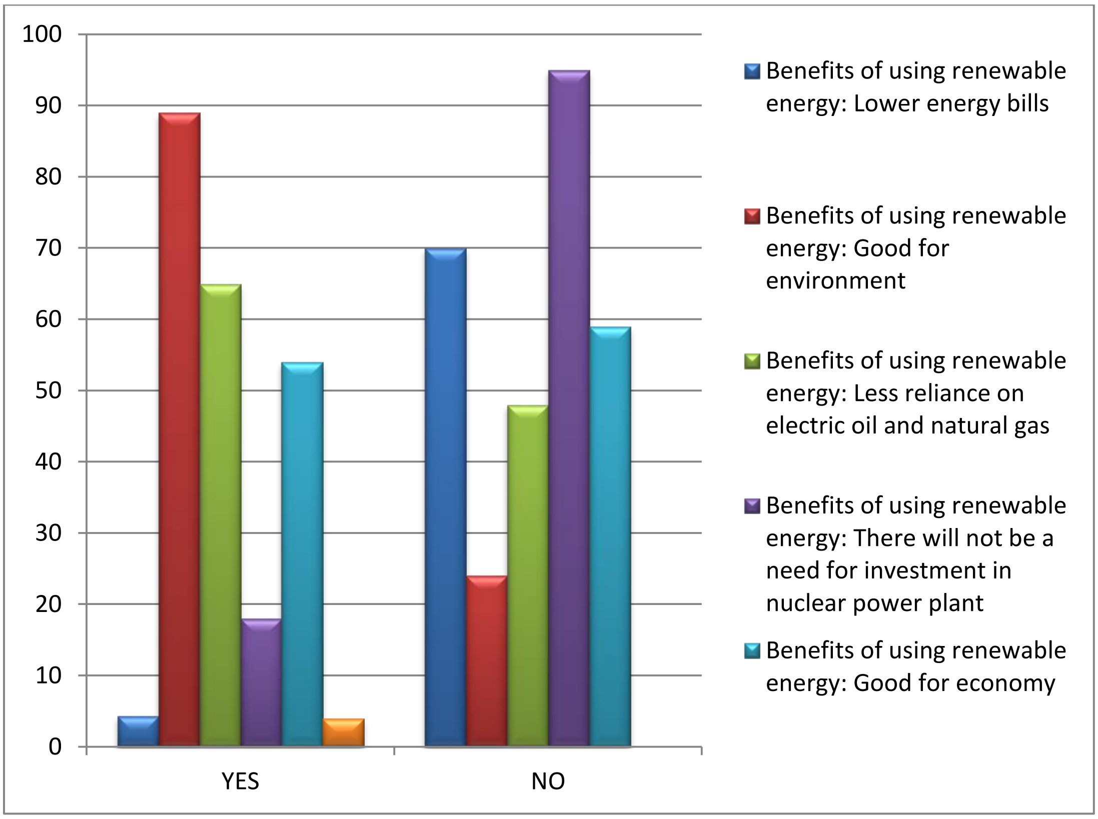

Figure 5.4: Benefits of RE (academics)

5.2.2 Attitude toward Renewable Energy

The academics' attitudes towards 'renewable energy 'were surveyed by eight items. The overall mean of all these items was calculated. The mean value represents agreement with the renewable energy. As the mean values increases, agreement with renewable energy increases. The overall mean of the attitude scale (M=4.21, SD=.697) shows that people have a very high attitude towards the renewable energy.

All the results related with their attitude towards 'renewable energy' are shown in the descending order of their mean values in Table 5.12.

Mean values show that the highest importance it attached to support for building clean renewable energy facilities to generate electricity in their local areas. The second highest mean value shows that people support the use of renewable energy. The third highest mean value shows that academics feel that 'The Kuwaiti government should ensure the study of renewable energy technologies in its education system (colleges and research centres)'. Percentage wise distribution of academics' opinion on five-level Likert answers of all questions related with 'Attitude towards Renewable Energy' Scale are shown in Table 5.12.

Answers to Q13 show that 92.9% of respondents support the use of renewable energy.

Answers to Q14 show that 100% of respondents support the building of 'clean' renewable energy facilities to generate electricity in their local areas.

Answers to Q15 show that 80.5% of respondents agree and 12.4% of respondents disagree regarding about 'The Kuwaiti government should support the pilot demonstration projects for every type of renewable energy technologies'.

Answers to Q16 show that 76.1% of respondents agree and 8.8% of respondents disagree about 'There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere'.

Answers to Q17 show that 84.1% of respondents agree and 7.1% of respondents disagree about 'The Kuwaiti government should ensure the study of renewable energy technologies in its education system (colleges and research centres)'.

Answers to Q18 show that 80.6% of respondents agree and 10.6% of respondents disagree about 'Using renewable energy sources is a way of looking after our future'.

Answers to Q19 show that 80.5% of respondents agree and 7.1% of respondents disagree about 'Renewable energy sources can play greater role in the world energy market'.

Answers to Q20 show that 77% of respondents agree and 5.3% of respondents disagree about 'Individual households should support the cost of using renewable energy'.

Table 5.12: Mean and SD of items related with Attitude towards RE (descending order of mean)

	Variables	*Mean*	*SD*
Q14	I support the building of 'clean' renewable energy facilities to generate electricity in my local area.	4.50	.502
Q13	I support the use of renewable energy.	4.47	.628
Q17	The Kuwaiti government should ensure the study of renewable energy technologies in its education system (colleges and research centres).	4.29	.903
Q18	Using renewable energy sources is a way of looking after our	4.26	1.007

	Variables	*Mean*	*SD*
	future.		
Q19	Renewable energy sources can play greater role in the world energy market.	4.12	.888
Q16	There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere.	4.07	1.108
Q15	The Kuwaiti government should support the pilot demonstration projects for every type of renewable energy technologies	4.01	.950
Q20	Individual households should support the cost of using renewable energy.	4.00	.886

Table 5.13: Percentage wise distribution of 'Attitude towards Renewable Energy'(academics)

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
13	I support the use of renewable energy.	.0	.0	7.1	38.9	54.0
14	I support the building of 'clean' renewable energy facilities to generate electricity in my local area.	.0	.0	.0	50.4	49.6
15	The Kuwaiti government should support the pilot demonstration projects for every type of renewable energy technologies	.0	12.4	7.1	47.8	32.7
16	There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere.	5.3	3.5	15.0	31.0	45.1
17	The Kuwaiti government should ensure the study of renewable energy technologies in its education system (colleges and research centres).	.0	7.1	8.8	31.9	52.2
18	Using renewable energy sources is a way of looking after our future.	.0	10.6	8.8	24.8	55.8
19	Renewable energy sources can play greater role in the world energy market.	.0	7.1	12.4	41.6	38.9
20	Individual households should support the cost of using renewable energy.	1.8	3.5	17.7	46.9	30.1

5.2.3 Awareness of Own Knowledge of RE and its Barriers

The academics' opinions regarding the 'awareness of own knowledge' towards 'renewable energy' was surveyed by 21 items. The overall mean of all these 21 items was calculated. The mean value represents knowledge about RE: as the mean values increase, people's knowledge about RE increases. The overall mean of the 'awareness of own knowledge' (M=3.82, SD=.425) shows that people have a reasonably good knowledge about RE (Table 5.14).

Table 5.14: Mean and SD of 'Awareness of Own Knowledge of Renewable Energy and its Barriers' (descending order)

Q	*Variables*	*Mean*	*SD*
27	Kuwait needs new environmental laws and regulations.	4.41	.820
25	Private sector should work with the government to create stable long-term investment in the renewable energy.	4.37	.746
33	Renewable energy technologies suffer from lack of awareness.	4.21	.784
28	There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.	4.14	.811
39	Renewable energy technologies suffer from the uncertain government policies and legislations.	4.11	.736
34	The Kuwaiti government needs to establish link between regional renewable energy research and local centres.	4.07	.863
36	Solar is considered a promising source of energy for Kuwait.	4.02	1.126
40	Renewable energy can create significant new employment opportunities in energy infrastructure manufacturing, installation, and maintenance.	4.01	.850
30	The harsh environment in Kuwait is well-suited for solar and wind renewable energies.	3.98	.779
24	Renewable energy technologies have technical barrier due to lack of skilled personnel, policy, and institutions.	3.97	.911
21	Renewable energy sources are environmentally sustainable energy supplies.	3.89	.849
22	Most of the air pollution in Kuwait is caused by production and use of oil and gas.	3.80	.857
35	There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.	3.73	.909
38	There are more advantages than disadvantages in using renewable energy technologies.	3.65	1.092
32	Renewable energy market failed due to government monopoly of energy supply.	3.60	.750
26	In the future we will no longer be able to use fossil fuels to generate electricity.	3.57	.885
41	Renewable energy technologies faces poor market due to lack of competition.	3.54	.877
37	Renewable energy technology products suffer from lack of social acceptance.	3.39	1.013
23	Renewable energy technology productions are very costly.	3.30	.934
31	Renewable energy technologies are more expensive than traditional fossil fuelled electricity supplies (such as coal, gas and oil)	3.29	1.163
29	Renewable energy technologies have environmental problems such as noise and visual intrusion.	3.21	1.039

The highest mean values (Mean=4.41, SD=0.82) show that majority of people feel that 'Kuwait needs new environmental laws and regulations'. The second highest mean value (Mean=4.37, SD=0.746) shows that people feel that 'Private sector should work with the government to create stable long-term investment in the renewable energy'. The third highest mean value (Mean=4.21, SD=0.784) shows that people feel that 'Renewable energy technologies suffer from lack of awareness'.

Percentage wise distribution of respondents' opinion of all questions related with 'Awareness of Own Knowledge of Renewable Energy and its Barriers 'for Academics is shown in Table 5.15.

Answers to Q21 show that 70.8% of respondents agree and 6.2% of respondents disagree with the statement: 'Renewable energy sources are environmentally sustainable energy supplies'.

Answers to Q22 show that 74.3% of respondents agree and 11.5% of respondents disagree with the statement: 'Most of the air pollution in Kuwait is caused by production and use of oil and gas'.

Answers to Q23 show that 46.9% of respondents agree and 24.8% of respondents disagree with the statement: 'Renewable energy technology productions are very costly'.

Answers to Q24 show that 75.2% of respondents agree and 8.8% of respondents disagree with the statement: 'Renewable energy technologies have technical barrier due to lack of skilled personnel, policy, and institutions'.

Answers to Q25 show that 91.2% of respondents agree and 3.5% of respondents disagree with the statement: 'Private sector should work with the government to create stable long-term investment in the renewable energy'.

Answers to Q26 show that 58.4% of respondents agree and 14.2% of respondents disagree with the statement: 'In the future we will no longer be able to use fossil fuels to generate electricity'.

Answers to Q27 show that 93% of respondents agree and 7% of respondents disagree with the statement: 'Kuwait needs new environmental laws and regulations'.

Answers to Q28 show that 87.6% of respondents agree and 7.1% of respondents disagree with the statement: 'There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system'.

Answers to Q29 show that 40.7% of respondents agree and 20.4% of respondents disagree with the statement: ‘Renewable energy technologies have environmental problems such as noise and visual intrusion’.

Answers to Q30 show that 76.1% of respondents agree and 3.5% of respondents disagree with the statement: ‘The harsh environment in Kuwait is well-suited for solar and wind renewable energies’.

Answers to Q31 show that 55.7% of respondents agree and 31% of respondents disagree with the statement: ‘Renewable energy technologies are more expensive than traditional fossil fuelled electricity supplies (such as coal, gas and oil)’.

Answers to Q32 show that 65.5% of respondents agree and 10.6% of respondents disagree with the statement: ‘Renewable energy market failed due to government monopoly of energy supply’.

Answers to Q33 show that 84.9% of respondents agree and 3.5% of respondents disagree with the statement: ‘Renewable energy technologies suffer from lack of awareness’.

Answers to Q34 show that 82.3% of respondents agree and 5.3% of respondents disagree with the statement: ‘The Kuwaiti government needs to establish link between regional renewable energy research and local centres’.

Answers to Q35 show that 73.4% of respondents agree and 15.9% of respondents disagree with the statement: ‘There is a lack of renewable energy educational programs and degrees in Kuwait’s higher education system’.

Answers to Q36 show that 76.9% of respondents agree and 19.5% of respondents disagree with the statement: ‘Solar is considered a promising source of energy for Kuwait’.

Answers to Q37 show that 60.2% of respondents agree and 22.1% of respondents disagree with the statement: ‘Renewable energy technology products suffer from lack of social acceptance’.

Answers to Q38 show that 65.5% of respondents agree and 23.9% of respondents disagree with the statement: ‘There are more advantages than disadvantages in using renewable energy technologies’.

Answers to Q39 show that 77.8% of respondents agree with the statement: ‘Renewable energy technologies suffer from the uncertain government policies and legislations’.

Answers to Q40 show that 82.3% of respondents agree and 8.8% of respondents disagree with the statement: ‘Renewable energy can create significant new employment opportunities in energy infrastructure manufacturing, installation, and maintenance’.

Answers to Q41 show that 54.9% of respondents agree and 10.6% of respondents disagree with the statement: ‘Renewable energy technologies face poor market due to lack of competition’.

Table 5.15: Percentage wise distribution of ‘Awareness of Own Knowledge of RE and its Barriers’ (Academics)

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
21	Renewable energy sources are environmentally sustainable energy supplies.	.0	6.2	23.0	46.0	24.8
22	Most of the air pollution in Kuwait is caused by production and use of oil and gas.	.0	11.5	14.2	57.5	16.8
23	Renewable energy technology productions are very costly.	.0	24.8	28.3	38.9	8.0
24	Renewable energy technologies have technical barrier due to lack of skilled personnel, policy, and institutions.	.0	8.8	15.9	44.2	31.0
25	Private sector should work with the government to create stable long-term investment in the renewable energy.	.0	3.5	5.3	41.6	49.6
26	In the future we will no longer be able to use fossil fuels to generate electricity.	.0	14.2	27.4	46.0	12.4
27	Kuwait needs new environmental laws and regulations.	.0	7.1	.0	38.1	54.9

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
28	There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.	.0	7.1	5.3	54.0	33.6
29	Renewable energy technologies have environmental problems such as noise and visual intrusion.	8.0	12.4	38.9	31.9	8.8
30	The harsh environment in Kuwait is well-suited for solar and wind renewable energies.	.0	3.5	20.4	50.4	25.7
31	Renewable energy technologies are more expensive than traditional fossil fuelled electricity supplies (such as coal, gas and oil)	7.1	23.9	13.3	44.2	11.5
32	Renewable energy market failed due to government monopoly of energy supply.	.0	10.6	23.9	60.2	5.3
33	Renewable energy technologies suffer from lack of awareness.	.0	3.5	11.5	45.1	39.8
34	The Kuwaiti government needs to establish link between regional renewable energy research and local centres.	1.8	3.5	12.4	50.4	31.9
35	There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.	.0	15.9	10.6	58.4	15.0
36	Solar is considered a promising source of energy for Kuwait.	.0	19.5	3.5	32.7	44.2
37	Renewable energy technology products suffer from lack of social acceptance.	5.3	16.8	17.7	54.0	6.2
38	There are more advantages than disadvantages in using renewable energy technologies.	.0	23.9	10.6	41.6	23.9
39	Renewable energy technologies suffer from the uncertain government policies and legislations.	.0	.0	22.1	45.1	32.7
40	Renewable energy can create significant new employment opportunities in energy infrastructure manufacturing, installation and maintenance.	.0	8.8	8.8	54.9	27.4
41	Renewable energy technologies faces poor market due to lack of competition.	1.8	8.8	34.5	43.4	11.5

5.2.4 Pearson Correlation Coefficient and T-test

Pearson Correlation Coefficient was computed between 'Overall Attitude towards Renewable Energy' Scale and 'Overall Awareness of Own Knowledge of Renewable Energy and its Barriers' Scale for 'Academics' and it was found that the correlation between them was very strong, positive and statistically significant at (0.001), r (111)=0.874, $p < 0.001$.

The reliability of all the items related with academics regarding their attitude and awareness knowledge was measured by applying SPSS Procedure 'Reliability Analysis using the Cronbach's Alpha'. The reliability of all the items regarding with their attitudes was achieved 0.916, which shows a level of very high internal consistency among all the items related with attitude scale.

The reliability of all the items regarding their awareness knowledge achieved 0.825, and this again shows that a level of high internal consistency among all the items related with awareness knowledge scale.

T-test was applied with respect to 'gender', 'age' and 'education' and ANOVA was applied with respect to 'country of education' on the 'Overall attitude variable' and on the 'Overall awareness knowledge of renewable energy' variables. The results are described below.

5.2.5. T-Test with respect to Gender

The following two research hypotheses are tested with respect to gender.

1. There is no statistically significant difference at (.05) with respect to 'Gender' on overall attitude to renewable energy.
2. There is no statistically significant difference at (.05) with respect to 'Gender' on overall awareness of own knowledge of renewable energy.

Table 5.16: T-Test with respect to Gender on 'Overall attitude to renewable Energy '&'Overall Awareness Knowledge of Renewable Energy' (academics)

Variables	*Gender*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	*η2*
Overall attitude to renewable energy	Female	61	4.48	0.611	4.695	111	0.000***	.166
	Male	52	3.91	0.671				
Overall awareness knowledge of renewable energy	Female	61	3.96	0.387	3.897	111	0.000***	.120
	Male	52	3.66	0.416				

*** $p \leq 0.001$; η2→ Partial Eta Squared

T-Test with respect to gender (female, male) was applied on ‘overall attitude to renewable energy’. As shown in Table 5.16, there is a statistically significant difference at (.001) with respect to ‘Gender’ on overall attitude to renewable energy, t (111)=4.695, $p \leq 0.0001$ (p=0.000). The mean values of ‘overall attitude to renewable energy’ show that female participants (M=4.48, SD=0.611) have much higher attitude about the renewable energy than male participants (M=3.91, SD=0.671) have. The strength of relationship between ‘gender’ variable and ‘overall attitude to renewable energy’, as assessed by η^2 (Partial Eta Squared), was very strong, with gender variable accounting for 17.0% of the variance of the ‘overall attitude’ variable.

T-Test with respect to gender (female, male) was applied on the ‘overall awareness of own knowledge of renewable energy’.

shows that there is a statistically significant difference at (.001) with respect to ‘Gender’ on overall awareness of own knowledge of renewable energy, t (111)=3.897, $p \leq 0.000$ (p=0.000). The mean values of ‘overall awareness of own knowledge of renewable energy’ show that female participants (M=3.96, SD=0.387) have much higher awareness of knowledge about the renewable energy than male participants (M=3.66, SD=0.416) have. The strength of relationship between ‘gender’ variable and ‘overall awareness of own knowledge of renewable energy’, as assessed by η^2 (Partial Eta Squared), was nearly strong, with gender variable accounting for 12.0% of the variance of the ‘overall awareness of own knowledge of renewable energy’ variable.

5.2.6. T-Test with respect to Age

The following two research hypotheses are tested with respect to age:

3. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall attitude to renewable energy.
4. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall awareness of own knowledge of renewable energy.

Table 5.17: T-Test with respect to Age on 'Overall attitude to renewable Energy' & 'Overall Awareness Knowledge of Renewable Energy' (academics)

Variables	*Age*	*N*	*Mean*	*SD*	*T*	*df*	*Sig. (2-tailed)*	η^2
Overall attitude to renewable energy	Up to 47	47	3.89	0.898	-3.960	57.377	.000***	.15
	More than 47	66	4.44	0.373				
Overall awareness knowledge of renewable energy	Up to 47	47	3.66	0.518	-3.355	67.393	.001***	.11
	More than 47	66	3.94	0.297				

*** $p \leq 0.001$; η^2→ Partial Eta Squared

T-Test with respect to age (up to 47, more than 47) was applied on 'overall attitude to renewable energy'. Table 5.17 shows that there is a statistically significant difference at (.001) with respect to 'Age' on overall attitude to renewable energy, t (57.377)=-3.96, $p \leq 0.001$ (p=0.000). The mean values of 'overall attitude to renewable energy' show that participants, who were in the age group of 'more than 47', have much higher attitude about the renewable energy (M=4.44, SD=0.373) than the participants who were in the age group of 'up to 47' have (M=3.89, SD=0.898).

The strength of relationship between 'age' variable and 'overall attitude to renewable energy', as assessed by η^2 (Partial Eta Squared), was very strong, with age variable accounting for 15.2% of the variance of the 'overall attitude' variable.

T-Test with respect to age was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.17 shows that there is a statistically significant difference at (.001) with respect to 'Age' on overall awareness of own knowledge of renewable energy, t (67.393)=-3.355, $p \leq 0.001$ (p=0.001). The mean values of 'overall awareness of own knowledge of renewable energy' show that participants, who were in the age group of 'more than 47', have much higher awareness knowledge about the renewable energy (M=3.94, SD=0.297) than the participants who were in the age group of 'up to 47' have (M=3.66, SD=0.518).

The strength of relationship between 'age' variable and 'overall awareness of own knowledge of renewable energy', as assessed by η^2 (Partial Eta Squared), was nearly strong, with age variable accounting for 11.0% of the variance of the 'overall awareness of own knowledge of renewable energy' variable.

5.2.7 T-Test with respect to Education (highest degree)

The following two research hypotheses were tested with respect to education:

5. There is no statistically significant difference at (.05) with respect to 'Education (Highest Degree Earned)' on overall attitude to renewable energy.
6. There is no statistically significant difference at (.05) with respect to 'Education (Highest Degree Earned)' on overall awareness of own knowledge of renewable energy.

Table 5.18: T-Test with respect to Education (Highest Degree Earned) on 'Overall attitude to renewable Energy '&'Overall Awareness Knowledge of Renewable Energy' (academics)

Variables	*Education*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	*η^2*
Overall attitude to RE	Doctorate	89	4.30	0.709	2.678	111	.009**	.06
	Master	24	3.89	0.545				
Overall awareness knowledge of RE	Doctorate	89	3.89	0.423	3.644	111	.000***	.11
	Master	24	3.56	0.320				

** $p \leq 0.01$; *** $p \leq 0.001$; η^2→ Partial Eta Squared

T-Test with respect to education (Doctorate, Master) was applied on 'overall attitude to renewable energy'. Table 5.18 shows that there is a statistically significant difference at (.01) with respect to 'Education' on overall attitude to renewable energy, t (111)=2.678, $p \leq 0.01$ (p=0.009). The mean values of 'overall attitude to renewable energy' show that participants, who had 'doctorate' qualification have much higher attitude about the renewable energy (M=4.30, SD=0.709) than the participants who had 'master' qualification (M=3.89, SD=0.545).

The strength of relationship between 'Education (Highest Degree Earned)' variable and 'overall attitude to renewable energy', as assessed by η^2 (Partial Eta Squared), was medium with education variable accounting for 6.0% of the variance of the 'overall attitude' variable.

T-Test with respect to education (Doctorate, Master) was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.18 shows that there is a statistically significant difference at (.001) with respect to 'Education' on overall awareness of own knowledge of renewable energy, t (111)=3.644, $p \leq 0.0001$ (p=0.000). The mean values of 'overall awareness of own knowledge of renewable energy' show that participants, who had 'doctorate' qualification have much higher awareness knowledge about the renewable energy (M=3.89, SD=0.423) than the participants who had ‘master’ qualification (M=3.56, SD=0.320).

The strength of relationship between ‘Education (Highest Degree Earned)’ variable and ‘overall awareness of own knowledge of renewable energy’, as assessed by η^2 (Partial Eta Squared), was nearly strong, with education variable accounting for 11.0% of the variance of the ‘overall awareness of own knowledge of renewable energy’ variable.

5.2.8 ANOVA by country of study

The following two research hypotheses are tested with respect to country of study:

7. There is no statistically significant difference at (.05) with respect to ‘Country of study’ on overall attitude to renewable energy.
8. There is no statistically significant difference at (.05) with respect to ‘Country of study’ on overall awareness of own knowledge of renewable energy.

Table 5.19: ANOVA by country of study on the ‘Overall Attitude’ & ‘Overall Awareness Knowledge’ of RE (academics)

Variables	*Country of study*	*N*	*Mean*	*SD*	*F*	*Sig.*	η^2
Overall attitude to RE	Kuwait	25	4.06	0.725	5.413	.006**	.09
	Europe	39	4.02	0.903			
	North America	49	4.45	0.351			
Overall awareness knowledge of RE	Kuwait	25	3.84	0.491	1.531	.221	.03
	Europe	39	3.73	0.525			
	North America	49	3.89	0.270			

** $p < 0.01$; $\eta^2 \rightarrow$ Partial Eta Squared

ANOVA was conducted to evaluate the relationship between Overall attitude to renewable energy and Country of study. The independent variable, ‘country of study’ factor, included three factors: Kuwait, Europe and North America, The dependent variable was ‘overall attitude to renewable energy’. The results in Table 5.19 show that the ANOVA was significant, $F (2, 110)=5.413$, $p \leq .01$, (p=.006). Follow-up tests were conducted to evaluate the pair wise differences among means. Test of ‘Homogeneity of variances’ show that variances differ significantly, thus using the Dunnett C procedure at (.05), it was found that there was a significant differences in the ‘overall attitudes of renewable energy’ between people who had their education in Kuwait (M=4.06, SD=.725) and the people who had their education in Europe (M=4.02, SD=.903).

It was also found that there was a significant differences in the ‘overall attitudes of renewable energy’ between people who had their education in Kuwait (M=4.06, SD=.725) and the people who had their education in North America (M=4.45, SD=.351).

The mean values also show that the people who studied in North America have got the highest attitude about the renewable energy.

The strength of relationship between three categories of ‘country of study’ and ‘overall attitude to renewable energy’, as assessed by η^2 (Partial Eta Squared), was more than medium with ‘country of study’ factor accounting for 9.0% of the variance of the dependent variable.

ANOVA was conducted to evaluate the relationship between ‘overall awareness of your own knowledge of renewable energy’ and country of study. The independent variable, ‘country of study’ factor, included three factors: Kuwait, Europe and North America, and the dependent variable was ‘overall awareness of your own knowledge of renewable energy’. Table 5.19 shows that the ANOVA was not significant, $F(2, 114)=1.531$, $p > .05$, ($p=.221$). The mean values show that people who studied in North America have got the highest awareness knowledge about renewable energy.

The strength of relationship between three categories of ‘country of study’ and ‘overall awareness of your own knowledge of renewable energy’, as assessed by η^2 (Partial Eta Squared), was less than medium, with ‘country of study’ factor accounting for 3.0% of the variance of the dependent variable.

5.3 Officials

5.3.1 Background on Renewable Energy

Of the ‘officials’ participants (n=117), 58 (49.6%) were female and 59 (50.4%) were male. 47 (40.2%) were in the age group of ‘up to 41 years old’ and 70 (59.8%) were in the age group of ‘more than 41 years old’. 42 (35.9%) were working as a ‘chemical or industrial engineer’, 56 (47.9%) were working as a ‘electrical engineer’, and 19 (16.2%) were working as a ‘research scientist’. The results of the background information is shown in Table 5.20

The results show that all the 68.4% of officials feel that they are environmentally conscious 62.4% are satisfied with the electric price that government of Kuwait has fixed. 76.1% support the subsiding of electricity that government of Kuwait is providing to all the people and private sector in of Kuwait. Notably, 86.3% support decreasing government electricity subsidy in order to promote renewable energy. 94.9% of officials intend to use renewable energy in future. This shows that majority of officials are in favour of renewable energy.

The official participants’ multiple opinions were taken regarding the kind of renewable energy they intend to use. The highest proportion (94.9%) support ‘solar energy’, followed by 63.2% for ‘wind energy’, and only 17.1% participants support ‘biomass energy’.

Table 5.20: Background information (officials)

Variables	*Yes* *No. (%)*	*No* *No. (%)*
Do you think that you are environmentally conscious?	80 (68.4)	37 (31.6)
Are you satisfied with the electricity price in Kuwait?	73 (62.4)	44 (37.6)
Do you support the Kuwaiti government subsidizing electricity?	89 (76.1)	28 (23.9)
Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?	117 (100)	0 (0)
Would you support decreasing government electricity subsidy in order to promote renewable energy?	101 (86.3)	16 (13.7)
Do you intend to use renewable energy in future?	111 (94.9)	6 (5.1)

The participants’ main consideration of using the renewable energy was ‘environment’ (78.6%) and the second main consideration was ‘cost effectiveness’ (19.7%). Only 1.7% of participants feel that it will be ‘reliable and efficient’.

About 56.4% participants feel that it is easy to start using RETs to generate energy in Kuwait, whereas 43.6% feel that it is very difficult. Officials’ opinions were taken regarding the question related with the benefits of using the renewable energy sources to generate electricity. Participants were asked to mention various benefits that they feel about the renewable energy sources; their responses are shown in Table 5.21.

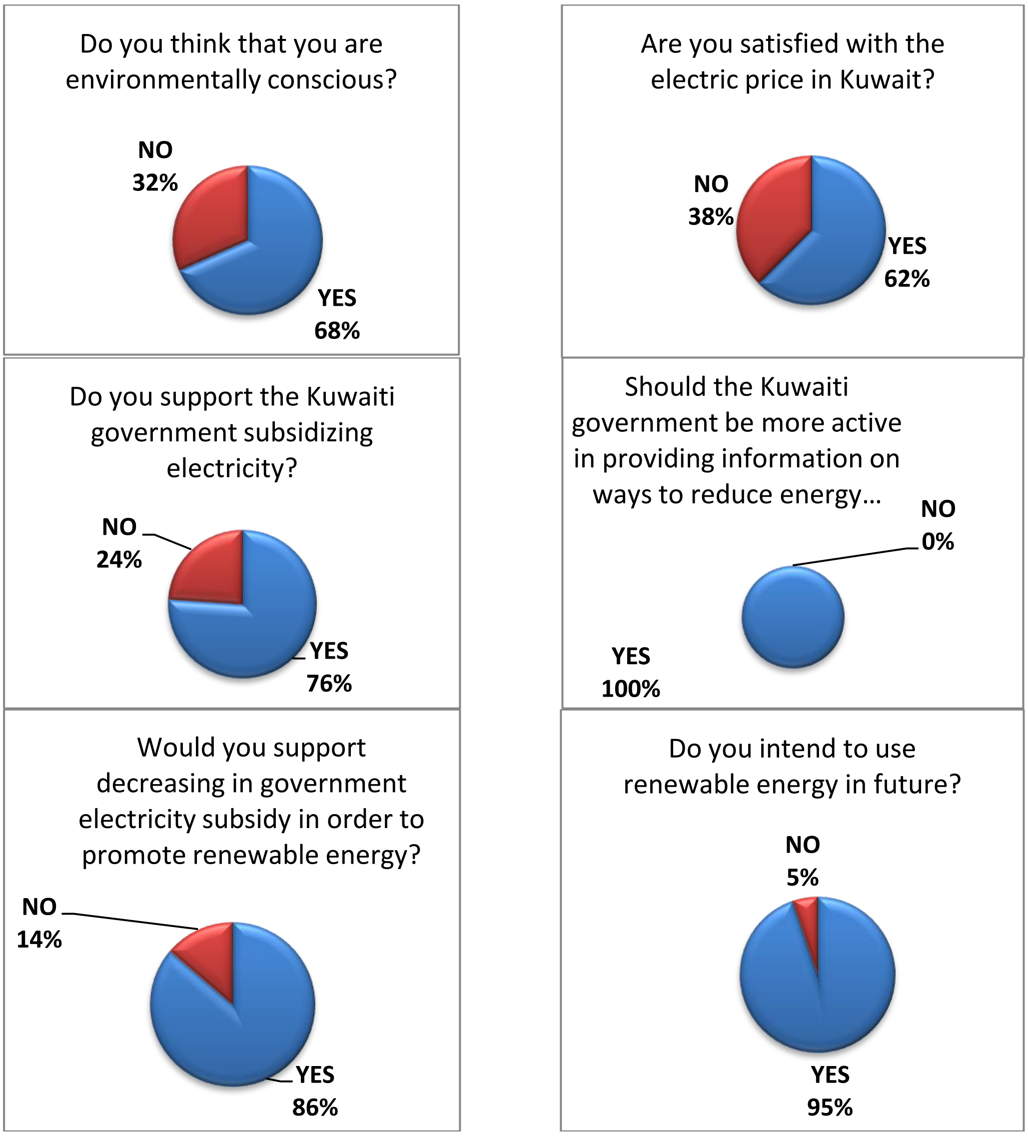

Figure 5.5: Background information (officials)

Table 5.21: Benefits of RE sources (officials)

Variables (perceived benefits of RE)	*Yes* *No. (%)*	*No* *No. (%)*
Lower energy bills	24 (20.5)	93 (79.5)
Good for environment	115 (98.3)	2 (1.7)
Less reliance on electric oil and natural gas	109 (93.2)	8 (6.8)
There will not be a need for investment in nuclear power plant	43 (36.8)	74 (63.2)
Good for economy	72 (61.5)	45 (38.5)
There is no benefit	0 (0)	117 (100)

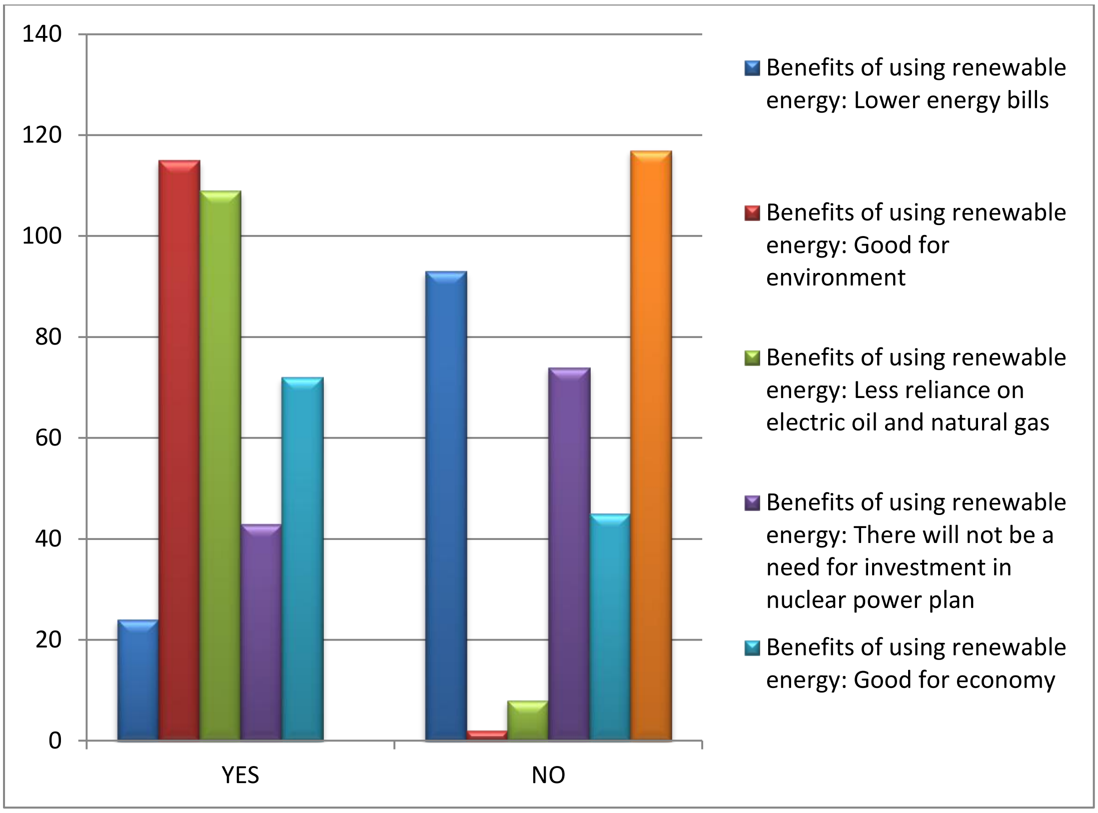

Figure 5.6: Benefits of RE (officials)

The highest benefits of RE were ascribed to the environment (98.3%) and then to less dependency on electric oil and natural gas (93.2%). 61.5% people feel that renewable energy will also be good for economy. Only 20.5% feel that it will help in lowering energy bills.

5.3.2 Attitude toward Renewable Energy

The officials' attitude towards 'renewable energy' was surveyed by five items, the means and standard deviations of which are shown in Table 5.22.

Table 5.22: Mean and standard deviation of items related with 'Attitude towards Renewable Energy' in descending order (officials)

Q	*Variables*	*Mean*	*SD*
15	I support the use of renewable energy	4.98	0.130
18	Renewable energy sources can play greater role in the world energy market	4.46	0.550
16	Individual households should support the cost of using renewable energy sources	2.96	1.719
17	With the existing petroleum, the Kuwaiti government should not waste time investing in renewable energy	2.07	1.711
19	Kuwait should continue using the existing source of energy (petroleum) powered generators for electricity production	1.76	1.031

The overall mean of all these five items was calculated. The mean value will represent the people agreement towards the renewable energy. As the mean values increase, people's agreement towards the renewable energy increases. The overall mean of the attitude scale (M=3.25, SD=.749) shows that people have reasonably positive attitudes toward renewable energy.

Mean values (Table 5.22) show that people regard the use of renewable energy as highly important. The second highest mean value shows that people feel that renewable energy sources can play a greater role in the world energy market.

Percentage wise distribution of officials' opinion concerning all questions related with 'Attitude towards Renewable Energy 'scale are shown in Table 5.23 and described below.

Responses to Q15 show that all respondents (100%) 'Support the use of the renewable energy'.

Responses to Q16 show that 52.2% of respondents disagree and 43.5% of respondents agree regarding the opinion that 'Individual households should support the cost of using renewable energy sources'.

Responses to Q17 show that 73.5% of respondents disagree and 26.5% of respondents agree regarding the opinion that 'With the existing petroleum, the Kuwaiti government should not waste time investing in renewable energy'.

Responses to Q18 show that more than 99.1% of respondents agree that 'Renewable energy sources can play greater role in the world energy market'.

Responses to Q19 show that 89.7% of respondents disagree and only 10.3% of respondents agree that 'Kuwait should continue using the existing source of energy (petroleum) powered generators for electricity production'.

Table 5.23: Percentage wise distribution for 'Attitude towards Renewable Energy' scale (officials)

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
15	I support the use of renewable energy	.0	.0	.0	1.7	98.3
16	Individual households should support the cost of using renewable energy sources	30.8	21.4	4.3	8.5	35.0
17	With the existing petroleum, the Kuwaiti government should not waste time investing in renewable energy	69.2	4.3	.0	3.4	23.1
18	Renewable energy sources can play a greater role in the world energy market	.0	.9	.0	51.3	47.9
19	Kuwait should continue using the existing source of energy (petroleum) powered generators for electricity production	48.7	41.0	.0	6.0	4.3

5.3.4 Awareness of Own Knowledge of RE and its Barriers

The 'awareness of own knowledge' towards 'renewable energy and its barriers' was surveyed by 13 items. Overall mean of all these 13 items was calculated. The mean value will represent the people knowledge towards the renewable energy. As the mean values increases, the people knowledge towards the renewable energy increases. The overall mean of the 'awareness of own knowledge (M=4.16, SD=.416) shows that people have high knowledge towards the renewable energy.

All the results regarding the 'awareness of own knowledge' towards 'renewable energy and its barriers' are shown in Table 5.24 in descending order of mean value.

It can be seen that the highest mean values (Mean=4.90, SD=0.305) indicate that the majority of the official participants feel that Kuwaiti power generation and water desalination depends heavily on gas and oil. The second highest mean value (Mean=4.75, SD=0.434) shows that people feel that the private sector should be involved in the investment of renewable energy technologies. The third highest mean value (Mean=4.58, SD=0.685) shows that officials feel that solar energy source should be considered a promising source of energy for Kuwait.

Percentage wise distribution of officials 'opinion among five levels Likert Scale of all questions related with 'Awareness of Own Knowledge of Renewable Energy and its Barriers' Scale is shown in Table 5.25 and described below:

Answers to Q20 show that 98.3% of respondents agree that ‘Per person, Kuwaitis use more electricity than most other people in the world’.

Answers to Q21 show that all the 100% of respondents agree that ‘Kuwaiti power generation and water desalination depends heavily on gas and oil’.

Answers to Q22 show that 37.6% of respondents disagree and 62.4% of respondents agree that ‘Renewable energy is more expensive than traditional fossil fuelled to generate electricity (such as coal, gas and oil)’.

Answers to Q23 show that 95.7% of respondents agree that ‘Renewable energy technologies suffer the lack of skilled personnel and institution research’.

Answers to Q24 show that 93.2% of respondents agree that ‘The harsh environment in Kuwait is well-suited for the solar and wind renewable sources’.

Answers to Q25 show that 73.5% of respondents agree and 11.9% of respondents disagree that ‘In the future, we will no longer be able to use fossil fuels to generate electricity’.

Answers to Q26 show that 35.9% of respondents agree and 18.8% of respondents disagree that ‘Renewable energy technologies are very costly due to lack of competition’.

Answers to Q27 show that 74.3% of respondents agree and 25.6% of respondents disagree that ‘Renewable energy technology products suffer lack of social acceptance’.

Answers to Q28 show that 94.1% of respondents agree that ‘Solar energy source is considered a promising source of energy for Kuwait’.

Answers to Q29 show that all 100% of respondents agree that ‘The private sector should be involved in the investment of renewable energy technologies’.

Answers to Q30 show that 91.5% of respondents agree that ‘There is a lack of renewable energy educational programs and degrees in Kuwait’s higher education system’.

Answers to Q31 show that about 94% of respondents agree that ‘There is a lack of reliable local data regarding the potential use and development of renewable energy technologies’.

Answers to Q32 show that more than 99% of respondents agree that ‘There are more advantages than disadvantages in using renewable energy’.

Table 5.24: Mean and standard deviation of all items related with ‘Awareness of Own Knowledge of Renewable Energy and its Barriers’ in descending order (officials)

Q	*Variables*	*Mean*	*SD*
21	Kuwaiti power generation and water desalination depends heavily on gas and oil	4.90	0.305
29	The private sector should be involved in the investment of renewable energy technologies	4.75	0.434
28	Solar energy source is considered a promising source of energy for Kuwait	4.58	0.685
32	There are more advantages than disadvantages in using renewable energy	4.56	0.593
24	The harsh environment in Kuwait is well-suited for the solar and wind renewable sources	4.39	0.719
20	Per person, Kuwaitis use more electricity than most other people in the world	4.37	0.519
23	Renewable energy technologies suffer the lack of skilled personnel and institution research	4.20	0.591
30	There is a lack of renewable energy educational programs and degrees in Kuwait’s higher education system	4.11	0.584
31	There is a lack of reliable local data regarding the potential use and development of renewable energy technologies	4.08	0.659
25	In the future, we will no longer be able to use fossil fuels to generate electricity	3.88	1.092
27	Renewable energy technology products suffer lack of social acceptance	3.82	1.157
26	Renewable energy technologies are very costly due to lack of competition	3.48	1.164
22	Renewable energy is more expensive than traditional fossil fuelled to generate electricity (such as coal, gas and oil)	3.02	1.438

Table 5.25: Percentage wise distribution of 'Awareness of Own Knowledge of Renewable Energy and its Barriers' (officials)

Q	*Variables*	*Strongly Disagree*	*Disagree*	*Undecided*	*Agree*	*Strongly Agree*
20	Per person, Kuwaitis use more electricity than most other people in the world	.0	.0	1.7	59.8	38.5
21	Kuwaiti power generation and water desalination depends heavily on gas and oil	.0	.0	.0	10.3	89.7
22	Renewable energy is more expensive than traditional fossil fuelled to generate electricity (such as coal, gas and oil)	29.1	8.5	.0	56.4	6.0
23	Renewable energy technologies suffer the lack of skilled personnel and institution research	.0	2.6	1.7	69.2	26.5
24	The harsh environment in Kuwait is well-suited for the solar and wind renewable sources	.0	3.4	3.4	43.6	49.6
25	In the future, we will no longer be able to use fossil fuels to generate electricity	5.1	6.8	14.5	41.9	31.6
26	Renewable energy technologies are very costly due to lack of competition	1.7	17.1	45.3	3.4	32.5
27	Renewable energy technology products suffer lack of social acceptance	.0	25.6	.0	41.0	33.3
28	Solar energy source is considered a promising source of energy for Kuwait	.0	2.6	3.4	27.4	66.7
29	The private sector should be involved in the investment of renewable energy technologies	.0	.0	.0	24.8	75.2
30	There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system	.0	1.7	6.8	70.1	21.4
31	There is a lack of reliable local data regarding the potential use and development of renewable energy technologies	.0	6.0	.0	74.4	19.7
32	There are more advantages than disadvantages in using renewable energy	.9	.0	.0	40.2	59.0

5.3.5 Reliability

Reliability of all the items regarding their attitude and awareness knowledge was measured by applying SPSS Procedure 'Reliability Analysis using the Cronbach's Alpha'. The reliability of all the items regarding with their attitudes was achieved 0.602 and this shows that a level of high internal consistency among all the items related with attitude scale.

The reliability of all the items regarding their awareness knowledge was achieved 0.751 and this again shows that a level of high internal consistency among all the items related with awareness knowledge scale.

5.3.6 Pearson Correlation Coefficient and T-test

Pearson Correlation Coefficient was computed between ‘Overall Attitude towards Renewable Energy’ Scale and ‘Overall Awareness of Own Knowledge of Renewable Energy and its Barriers’ Scale for ‘Officials’ and it was found that the correlation between them was medium, negative and statistically significant at (0.001), $r(115)=-0.371$, $p < 0.001$.

5.3.7 Creating Overall Attitude and Overall Awareness Knowledge Variable

Two new variables ‘overall attitude’ and ‘overall awareness knowledge’ were created by adding and dividing by number of variables related with their respect scales.

Overall mean attitude of all the 117 participants regarding the renewable energy was 3.25 with a standard deviation as 0.749. Overall mean value of their ‘awareness knowledge’ regarding the renewable energy was 4.16’ with a standard deviation as 0.416. This shows that overall people were in favour of renewable energy.

T-test was applied with respect to ‘gender’ and ‘age’ and one way analysis of variance (ANOVA) was applied with respect to ‘occupation’ on these two newly created variables, ‘overall attitude to renewable energy’ and ‘overall awareness knowledge of renewable energy’ variables. The results are explained below.

5.3.8 T-Test for Gender

The following two research hypotheses are tested with respect to gender.

1. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall attitude to renewable energy.

2. There is no statistically significant difference at (.05) with respect to ‘Gender’ on overall awareness of own knowledge of renewable energy.

T-Test with respect to gender (female, male) was applied on ‘overall attitude to renewable energy’. Results (Table 5.25) show that there is a statistically significant difference at (.001) with respect to ‘Gender’ on overall attitude to renewable energy, $t(112.35)=-11.479$, $p \leq 0.001$ ($p=0.000$). The mean values of ‘overall attitude to renewable energy' show that male participants (M=3.79, SD=0.477) have much higher attitude about the renewable energy than female participants (M=2.70, SD=0.547) have.

The strength of relationship between 'gender' variable and 'overall attitude to renewable energy', as assessed by η^2 (Partial Eta Squared), was very strong, with gender variable accounting for 53.5% of the variance of the 'overall attitude' variable.

T-Test with respect to gender (female, male) was applied on the 'overall awareness of own knowledge of renewable energy'. Table 5.25 shows that there is a statistically significant difference at (.001) with respect to Gender on overall awareness of own knowledge of renewable energy, t (115)=8.332, $p \leq 0.001$ (p=0.000). The mean values of 'overall awareness of own knowledge of renewable energy' show that female participants (M=4.42, SD=0.362) have much higher awareness of knowledge about the renewable energy than male participants (M=3.91, SD=0.295).

The strength of relationship between 'gender' variable and 'overall awareness of own knowledge of renewable energy', as assessed by η^2 (Partial Eta Squared), was very strong, with gender variable accounting for 37.6% of the variance of the 'overall awareness of own knowledge of renewable energy' variable.

Table 5.26: T-Test with respect to Gender on 'Overall attitude to renewable Energy '&'Overall Awareness Knowledge of Renewable Energy' (officials)

Variables	*Gender*	*N*	*Mean*	*SD*	*T*	*df*	*Sig. (2-tailed)*	η^2
Overall attitude to RE	Female	58	2.70	.547	-11.479	112.35	0.000**	.535
	Male	59	3.79	.477				
Overall awareness knowledge of RE	Female	58	4.42	.362	8.332	115	0.000**	.376
	Male	59	3.91	.295				

** $p \leq 0.001$; η^2 → Partial Eta Squared

5.3.9 T-Test for Age

The following two research hypotheses were tested with respect to age.

3. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall attitude to renewable energy.

4. There is no statistically significant difference at (.05) with respect to ‘Age’ on overall awareness of own knowledge of renewable energy.

T-Test with respect to age (up to 41, more than 41) was applied on ‘overall attitude to renewable energy’. Table 5.27 shows that there is a statistically significant difference at (.05) with respect to ‘Age’ on overall attitude to renewable energy, t (105.252)=-2.045, $p \leq 0.05$ (p=0.043). The mean values of ‘overall attitude to renewable energy’ show that participants, who were in the age group of ‘more than 41’, have much higher attitude about the renewable energy (M=3.35, SD=0.881) than the participants who were in the age group of ‘up to 41’ have (M=3.09, SD=0.458).

The strength of relationship between ‘age’ variable and ‘overall attitude to renewable energy’, as assessed by η^2 (Partial Eta Squared), was weak, with age variable accounting for 2.8% of the variance of the ‘overall attitude’ variable.

T-Test with respect to age was applied on the ‘overall awareness of own knowledge of renewable energy’. Table 5.27 shows that there is no statistically significant difference at (.05) with respect to ‘Age’ on overall awareness of own knowledge of renewable energy, t (115)=-0.119, $p > 0.05$ (p=0.905). The mean values of ‘overall awareness of own knowledge of renewable energy’ show that participants aged ‘more than 41’ have much higher awareness knowledge about renewable energy (M=4.17, SD=0.427) than participants aged ‘up to 41’ (M=4.16, SD=0.402).

Table 5.27: T-Test with respect to Age on ‘Overall attitude to renewable Energy’ & ‘Overall Awareness Knowledge of Renewable Energy’ (officials)

Variables	*Age*	*N*	*Mean*	*SD*	*t*	*df*	*Sig. (2-tailed)*	η^2
Overall attitude to RE	Up to 41	47	3.09	.458	-2.045	109.252	0.043*	.028
	More than 41	70	3.35	.881				
Overall awareness knowledge of RE	Up to 41	47	4.16	.402	-0.119	115	0.905	.000
	More than 41	70	4.17	.427				

* $p \leq 0.05$; η^2 → Partial Eta Squared

5.3.10 ANOVA by Occupation

The following two research hypotheses were tested with respect to occupation.

5. There is no statistically significant difference at (.05) with respect to ‘Occupation’ on overall attitude to renewable energy.

6. There is no statistically significant difference at (.05) with respect to ‘Occupation’ on overall awareness of own knowledge of renewable energy.

ANOVA was conducted to evaluate the relationship between ‘Overall attitude to renewable energy’ and Occupation. Table 5.28 shows that the ANOVA was significant, F (2, 114)=6.652, p $\leq$ .005, (p=.002). Follow-up tests were conducted to evaluate the pair wise differences among means. Test of ‘Homogeneity of variances’ show that variances differ significantly, thus using the Dunnett C procedure at (.005), it was found that there was a significant differences in the ‘overall attitudes of renewable energy’ between people working as ‘chemical or industrial engineers’ (M=3.10, SD=0.455) and people working as ‘Research Scientists’ (M=3.79, SD=0.641). It was also found that there was a significant differences in the ‘overall attitudes of renewable energy’ between people working as ‘electrical engineers’ (M=3.17, SD=0.877) and people working as ‘Research Scientists’ (M=3.79, SD=0.641). The mean values also show that research scientists have got the highest attitude about the renewable energy.

The strength of relationship between three categories of occupation and ‘overall attitude to renewable energy’, as assessed by η^2 (Partial Eta Squared), was nearly strong, with occupation factor accounting for 10.5% of the variance of the dependent variable.

ANOVA was conducted to evaluate the relationship between ‘overall awareness of your own knowledge of renewable energy’ and Occupation. Table 5.29 shows that the ANOVA was significant, F (2, 114)=9.474, p $\leq$ .005, (p=.000). Follow-up tests were conducted to evaluate the pair wise differences among means. Test of ‘Homogeneity of Variances’ show that variances differ significantly, thus using the Dunnett C procedure at (.005), it was found that there was a significant differences in the ‘overall awareness of your own knowledge of renewable energy’ between people working as ‘chemical or industrial engineers’ (M=4.03, SD=0.434) and people working as ‘research scientists’ (M=3.85, SD=0.509). It was also found that there was a significant differences in the ‘overall awareness of your own knowledge of renewable energy between people working as ‘electrical engineers’ (M=4.29, SD=0.295) and people working as ‘research scientists’ (M=3.85, SD=0.509). The mean values also show that electrical engineers have the highest awareness knowledge about renewable energy.

The strength of relationship between three categories of occupation and ‘overall awareness knowledge of renewable energy’, as assessed by η^2 (Partial Eta Squared), was strong, with occupation factor accounting for 14.3% of the variance of the dependent variable.

Table 5.28: ANOVA by Occupation on ‘Overall Attitude’ & ‘Overall Awareness Knowledge’ of Renewable Energy’ (officials)

Variables	*Occupation*	*N*	*Mean*	*SD*	*F*	*Sig.*	*η^2*
Overall attitude to RE	Chemical or industrial engineer	42	3.10	.455	6.652	.002***	.105
	Electrical engineer	56	3.17	.877			
	Research scientist	19	3.79	.641			
Overall awareness knowledge of RE	Chemical or industrial engineer	42	4.13	.434	9.474	.000***	.143
	Electrical engineer	56	4.29	.295			
	Research scientist	19	3.85	.509			

*** $p \leq 0.005$; η^2 → Partial Eta Squared

The overall results of the investigation of the attitudes of the public, academics and officials are explained below.

5.4 Findings of the Questionnaire

5.4.1 The Public

The public attach the highest importance to decreasing the use of household energy consumption in order to protect the environment. They feel that most of the air pollution in Kuwait is caused by the production and use of fossil fuels and believe that renewable energy sources are the most environmentally sustainable source. Overall, public participants do not believe that RE technologies cause environmental problems such as noise and visual intrusion.

With respect to the variable gender, the result shows that male public participants show high level of overall attitude regarding RE and awareness of own knowledge of RE. With respect to age variable, the results show that the public participants aged over 37 have much higher attitude and awareness of own knowledge of RE than those aged under 37. With respect to the education variable, public participants with postgraduate education had better attitudes and knowledge that those educated to graduate level or less.

5.4.2 Academics

The academics feel that the greatest benefit of RE is for the environment, followed by economic advantages and finally reduced dependence on fossil fuels to generate electricity. Almost half of the academics believed that it is difficult to start using RE in the absence of legislation to regulate it. They also urged the government and private institutions should establish RE education programs or curriculums to cover the training of skilled personnel and to create more employment opportunities from RET. A large majority of academics support solar energy rather than wind or biomass.

Half of the academics believe that RE production is costly and more expensive than the production of energy from traditional sources, and that the Kuwaiti government lacks comprehensive and cohesive legislation and regulations for the environment and RE. The absence of educational program and degree in Kuwait higher education led to lacking the skilled personnel and institutions. Moreover, most academics think that RE suffers from lack of social acceptance and awareness; moreover, they believe that RE suffers from poor market due to lack of competition and Kuwaiti government monopoly of energy supply.

With respect to the gender variable, female participants show much higher attitudes and awareness of own knowledge of RE than males. With respect to the age variable, participants aged over 47 show higher attitude and knowledge of RE than those aged up to 47. With respect to the variable education, academics with doctoral qualifications have much higher attitude and knowledge than master’s degree holders. With respect to country of graduation, show that participants whose degree was from the US have higher attitude and knowledge than those who earned their degrees from Kuwait or Europe.

5.4.3 Officials

Surprisingly, the officials were the least likely among participants to be concerned about the effects on environmental air quality of pollutants released into the atmosphere from fossil fuels. However, they are in favour of RE and support the idea of reducing the subsiding of the electricity for the benefits of investing in RE sources and technologies. They believed that RE can play greater role in the world energy market. More than half of the officials believe that RE is expensive, but required not only for the purpose of clean energy but also for economic benefits.

With respect to gender, male officials showed higher attitudes toward RE, however female officials showed higher awareness of own knowledge about RE. With respect to the age variable, the age group over 41 have much a higher attitude toward and knowledge of RE than those aged under 41. Regarding the occupation variable, officials working as ‘research scientists’ have stronger attitudes toward RE, however officials working as ‘chemical or industrial engineers’ have more knowledge about it.

CHAPTER 6: COST ANALYSIS

6.1 Introduction

Kuwait is located in the Arabian Peninsula at the northwest corner of the Arabian Gulf between 28^{o} and 30^{o} latitude, 46^{o} and 48^{o} longitude. Kuwait shares borders to the south with Saudi Arabia, and to the north with Iraq. The total land area is approximately 17,818 km^{2}; the land is mostly flat, gradually sloping towards sea level in the east. The western borderland is 270 meters above sea level. About 6% of the land in Kuwait is populated [171]. Since the discovery of oil and gas in Kuwait, a notable increase in infrastructural development and population growth has occurred. According to [171], the current population in Kuwait is 3,965,000. The main and only original energy sources in Kuwait are oil and natural gas; those sources are managed by a state-owned entity, the Kuwait Petroleum Corporation (KPC), which with its subsidiaries is responsible for oil and gas production, manufacturing, exporting and distribution. The main use of energy locally is for electricity and water desalination, industry and transportation, which respectively claim 65%, 20% and 15% of local primary fuel consumption [172].The increase of development in infrastructure and population led to increased demand for electricity and fresh water. The current total electricity installed capacity is close to 12 GW and the water desalination capacity is about 450 million imperial gallons per day [172].

Table 6.1 presents the positive correlation between population increase and per capita consumption, peak demand and installed capacity [144]. Both [172] and [140] claimed that residential buildings consume a high percentage of electricity, which can reach up to 70% of the total production. With the oil production rate of 2008, all the produced oil would be consumed locally by 2027 [142].

Table 6.1: Population per capita consumption, peak demand & installed capacity [144]

Year	Population	Per Capita Consumption (kWh)	Peak Demand (MW)	Installed Capacity (MW)
1981	1464808	6032	2290	2686
1992*	1441385	9858	3460	6898
2001	2309102	12678	6750	9189
2011	3697292	13633	11220	14702.7

6.2 Generating Electricity and Water Desalination

In 2008 Kuwait was rated one of the world's highest per capita power consumers with 16.75 MWh/capita and a power capacity of around 11,600 MW, which figure would have to double by 2020 to meet rising demands [173]. In the period from 2003 to 2008, the consumption of both electricity and water increased by 34% over five years, whereas the MEW estimates that consumption will increase by 51% for electricity and 65% for water for the next five years [140]. In 2013 the EIA [174] claimed that in 2010 Kuwait consumed more natural gas than it produced. To make up for this supply cap, since 2009 Kuwait has imported liquefied natural gas (LNG) from its neighbours including Yemen, Oman and Qatar. Therefore, Kuwait plans to increase gas production to 113 million m^3/day in efforts to satisfy local consumption and plans to add 10,000 MW, approximately doubling its generation capacity by 2015 [150]. Figure 6.1 presents the production and consumption for natural gas from 2000-2010, and Figure 6.2 shows electricity capacity and consumption from 1998-2008.

The consumption of electricity in Kuwait is expected to witness a considerable annual increase of about 5.3 percent [175]. This increase is despite the repeatedly executed campaigns for growing public awareness about rationalization of power consumption; these reasons are mainly the governmental subsidy of power and the considerably low price rate.

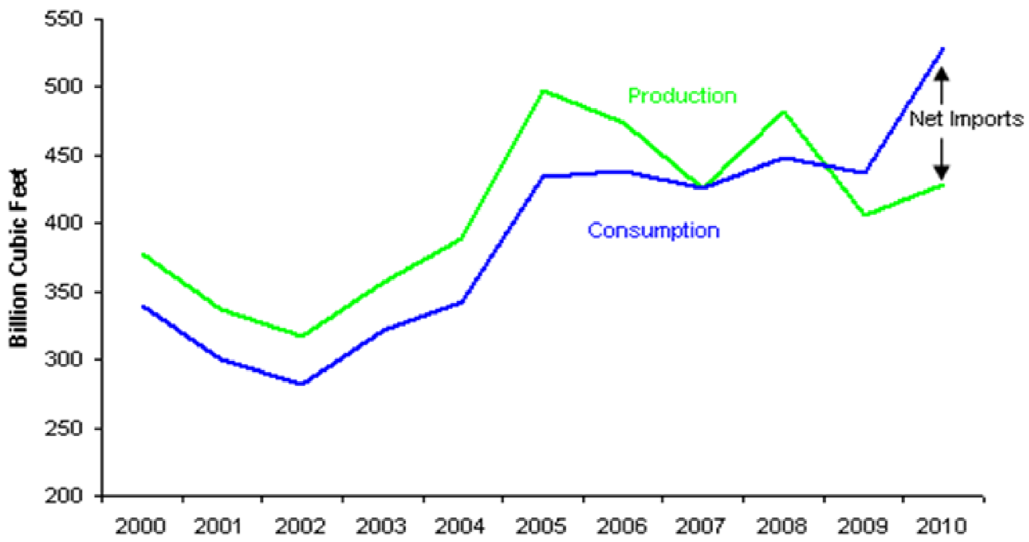

Figure 6.1: Kuwaiti gas production and consumption 2000-2010 [144]

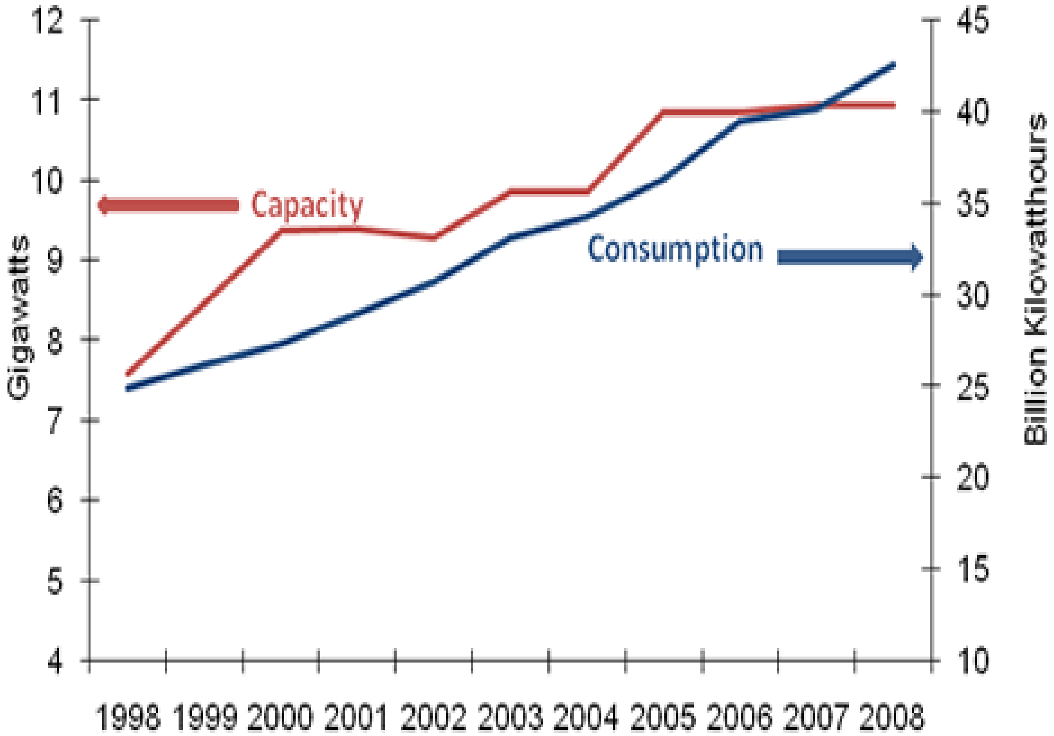

Figure 6.2: Kuwait electricity capacity and consumption 1998-2008 [144]

The cost of electricity generation in Kuwait is the highest in the world [176]. Since 1966, the cost of one kW of electricity generated in Kuwait is 38 fills: the consumers pay two fills and the Kuwaiti government pays 36, as a result of which electricity subsidy comprises a major burden on the government budget [149]. Table 6.2 presents the subsidy price from 1953 to the present and Figure **6.3** presents the cost and price of electricity from 2004-2011. Kuwait's population is expected to reach 4.34 million by 2017 compared to 3.68 million up to date [150]. MEW announced that the expansion of electricity demand would reach 25,000 megawatts by 2030, compared to 11,000 at present.

Currently, MEW has seven plants for generating electricity, with a total capacity of 13.23×10^3 MW. The annual electrical consumption is currently about 11×10^3 MW, and it is expected to increase to 25 thousand megawatts by 2030 [144]. While those power generating station consume about 200,000 to 300,000 oil barrels every day to cover the production of 71% of its electric needs, RES such as solar and wind contribute 2-3% of the escalating energy needs of the country. Table 6.3 presents the energy produced in Kuwait from the year 1992-2013, and the predicted energy that will be generated from 2014 to 2020.

Having highlighted the significant increase and cost of energy in Kuwait, the use of fossil fuels has created a tremendous damage to the environment, such as CO_2 emission. CO_2 emissions arise from many sources, such as electricity production, transportation, household use and industrial applications. The Index Mundi contains GHG emissions data from each country collected from many sources [177]. Data of CO_2 emissions in Kuwait are available for the period 1971 to 2010, as presented in Table 6.4. According to [176], the per capita CO_2 release in Kuwait is among the highest in the world. The current CO_2 emitted due to electricity generation and water desalination is almost 40 million tons per day, expected to be 70 million tons per day by 2030. Figure 6.4 below shows the emission of CO_2 in Kuwait by sector. The heavy financial burden and dire economic implications of rising energy use under the current system of electricity generation in Kuwait, along with Kuwait's poor record with regard to CO_2 emissions and obligations to comply with the Kyoto protocol, have forced the Kuwaiti government to look for another source of energy that is renewable, clean and non-hazardous to human health and the environment.

Table 6.2: Subsidy price for energy from 1953 to present [148]

Year	kW price in fills
1953	27.0
1953-1955	18.0
1955-1960	13.5
1961-1964	7.5
1964-1965	2.0
1966-2014	2.0

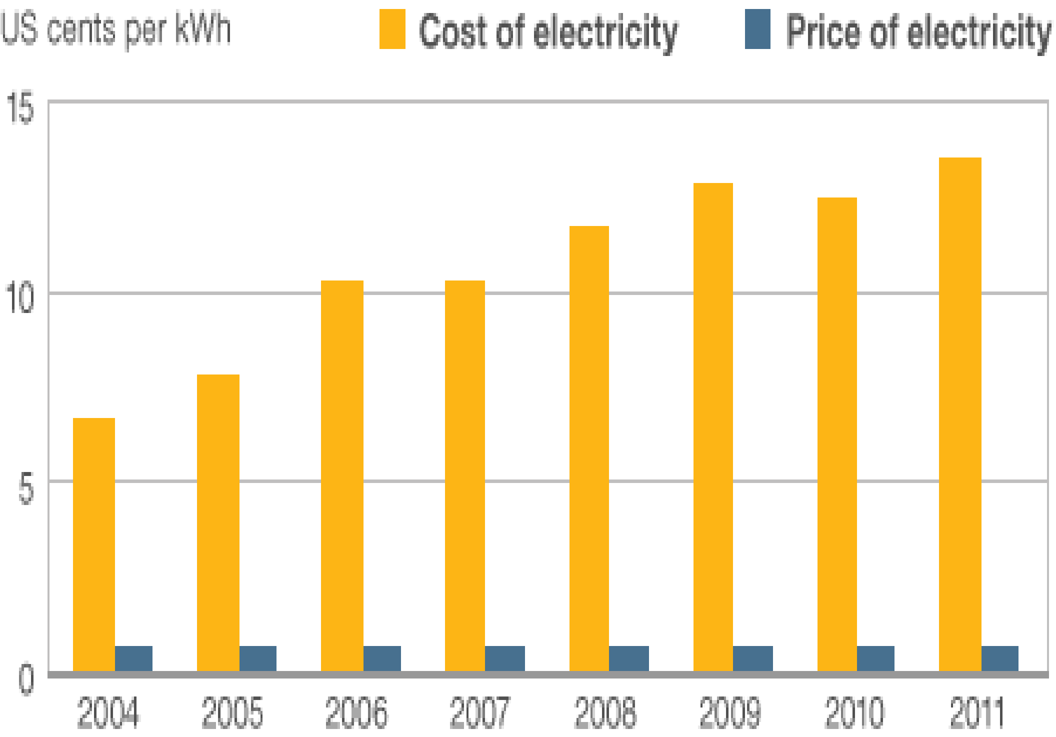

Figure 6.3: The gap between the cost and price of electricity in Kuwait [144]

Table 6.3: Energy generation 1992-2013, and projected energy from MEW 2014- 2020 [144]

Year	Electricity Generation (million kWh)	Percentage Annual Increase/Decrease (%)
1992	16885	N/A
1993	20178	19.5
1994	22802	13.0
1995	23724	4.0
1996	24575	3.5
1997	26724	8.7
1998	29984	12.1
1999	31576	5.3
2000	32323	2.3
2001	34299	6.1
2002	36362	6.0
2003	38577	6.0
2004	41257	6.9
2005	43734	6.0
2006	47605	8.8
2007	48754	2.4
2008	51749	6.1
2009	53216	2.8
2010	57082	7.2
2011	57489	0.7
2012	62054	7.9
2013	67018	7.9
Projected		
2014	*72379*	*7.9*
2015	*78170*	*8.0*
2016	*84423*	*7.9*
2017	*90333*	*7.0*
2018	*96656*	*6.9*
2019	*103422*	*7.0*
2020	*110662*	*7.0*

Table 6.4: Kuwaiti CO_2 emissions 1971-2010 [177]

Year	CO_2 emission (MMT)	Year	CO_2 emission (MMT)
1971	6.09	1991	4.78
1972	6.75	1992	11.96
1973	7.06	1993	16.08
1974	7.00	1994	21.13
1975	7.06	1995	20.69
1976	7.87	1996	21.00
1977	8.70	1997	22.28
1978	9.48	1998	26.15
1979	12.38	1999	30.88
1980	11.68	2000	32.21
1981	11.06	2001	36.44
1982	12.88	2002	38.49
1983	14.10	2003	37.36
1984	15.50	2004	40.16
1985	16.87	2005	44.42
1986	18.50	2006	46.78
1987	19.35	2007	48.24
1988	21.64	2008	51.01
1989	23.41	2009	56.74
1990	20.66	2010	60.21

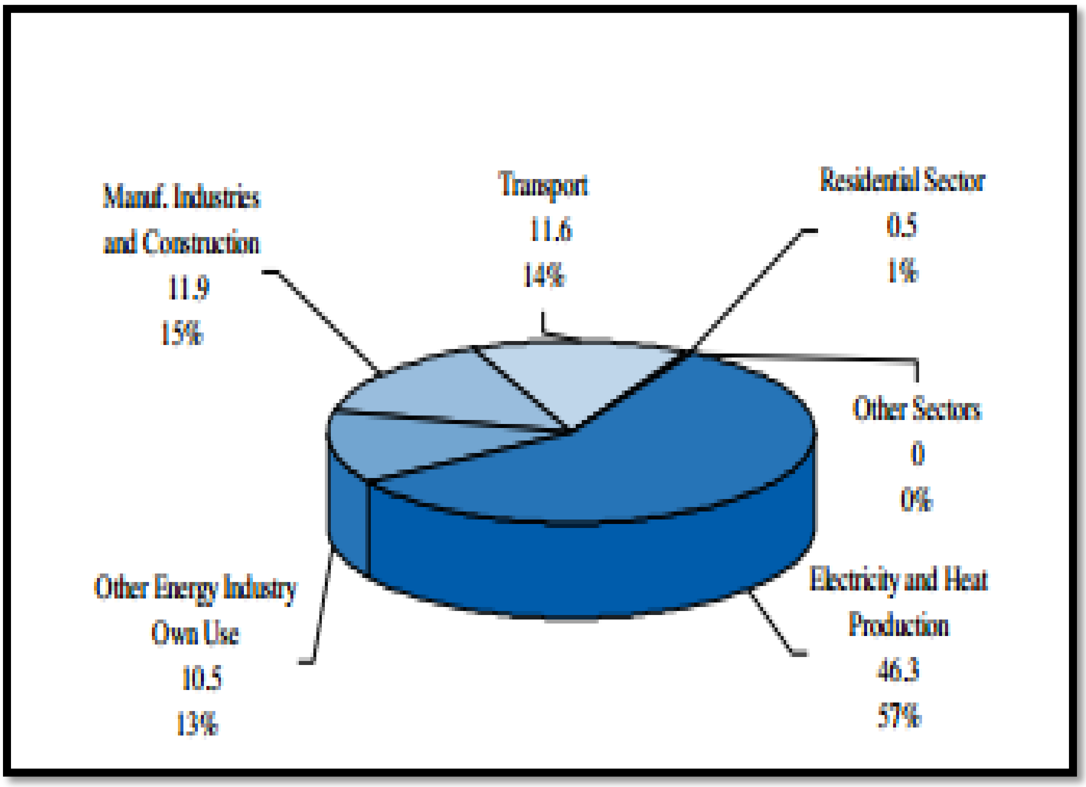

Figure 6.4: Kuwait fuel combustion CO_2 emissions by sector, 2009 [173]

6.3 Renewable Energy Possibilities in Kuwait

The harsh environment, low levels of rainfall, low cloud cover and large abundance of space (about 92% unpopulated) in Kuwait renders the country well suited for investment in RES, especially solar and wind. In Kuwait, there is almost universal high exposure to solar radiation during the daylight hours, with an average of nine hours of sunshine per day throughout the year. According to [178], Kuwait's annual solar irradiation is estimated at around 2100-2200 kWh/m^2. They claimed that Kuwait's average daily irradiation is very high compared with countries that are among the main users of solar energy, such as Germany and Spain. Indeed, the German Aerospace Centre (GAC) studied the concentration of solar power in the region and found that Kuwait has the highest Direct Normal Irradiance (DNI) of CSP, with 2,100 kWh/m^2/year, and 1,900 kWh/m^2/year of Global Horizontal Irradiance (GHI), suitable for photovoltaic systems [179], which represents enormous solar energy and great potential for solar-based generation of electricity [173]. In terms of wind energy, KISR studied the potential and applicability of wind energy in Kuwait [151]. It was found that the annual average wind speed for the several inland flat desert areas ranged from 3.7 to 5.5 m/s. In addition, the wind power density in the open flat desert areas varies between 209 kWh/m^2/year and 425 kWh/m^2/year, and reached maximum of 891 kWh/m^2/year in the summer. The study concluded that Kuwait has great potential of wind energy for local and industrial use.

6.4 Al-Shagaya Renewable Energy Project

The Research and Development Institute at the Kuwait Institute for Scientific Research (KISR) has launched its Innovative Renewable Energy Research (IRER) program. The program includes the implementation of renewable energy multi-technology power, called Al-Shagaya Renewable Energy Project. A 100 kilometre^2 (38.6 mile^2) site in Al-Shagaya – a desert area 100 km (62 miles) west of Kuwait City, near the borders with Saudi Arabia and Iraq – has been designated for this project. While the first phase will be financed by the government, the second and third phases will be offered to investors on a Build-Operate-Transfer (BOT) basis for 25 years, during which the government pledges to buy all output. The project includes 70 MW of different commercially proven technologies, mainly 50 MW parabolic trough technology equipped with Thermal Energy Storage (TES) system, and backed up by fuel boilers of about 10 MW photovoltaic and 10 MW wind [151].

Al-Shagaya will increase from baseline capacity of 10 MW wind energy, 10 MW PV, and 50 MW thermal, equipped with 10-hour energy storage that will let the plant work after sunset, via three phases:

- Phase 1: project with 70 MW of RE capacity (50 MW CSP, 10 MW PV and 10 MW wind);
- Phase 2: extension of the plant to a total of 1,000 MW installed RE capacity (CSP, CPV, PV and /or wind);
- Phase 3: extension of the plant to a total of 2,000 MW installed RE capacity (CSP, CPV, PV and /or wind).

The second phase will expand the plant's capacity by 930 MW to bring it up to 1,000 MW, and the third by another 1,000 MW to ultimately reach 2,000 MW by 2030. By then, the complex will generate more than 5,000,000 MWh of energy every year, fulfilling the demands of nearly 100,000 households.

6.5 The Aim and Objectives of Al-Shagaya Project

According to R&D [151], the purpose behind the development of the Al-Shagaya project is to enable the assessment of the performance of different renewable energy technologies employed by Kuwait. These various technologies are PV, CSP, and wind in addition to energy storage with and without co-firing capacities under local climate conditions. There are five existent specific objectives of the Al-Shagaya project:

1. Design, construct, commission and operate 70 multi technology renewable energy power plants;
2. Evaluate the performance, efficiency and reliability of the technologies used and determine the deficiencies and limitations of each technology under local climate conditions;
3. Assess the performance of national electrical system analysis and network stability under large scale renewable energy power generations;

4. Conduct precise and accurate technical and economic feasibility and cost benefit analysis for large scale deployment of each technology used for power generation in Kuwait; and
5. Develop the local human capacity and hands-on experience for Kuwaiti engineers.

It is targeted that RES will contribute up to 15% of Kuwait's total power production by 2030 [152].

6.6 Cost-Benefit Analysis of MEW and Al-Shagaya Electricity Generation to 2030

6.6.1 Estimating Kuwait's Energy Requirements to 2030

MEW has published data on energy consumed in Kuwait for the period 1991 to 2013 and also predicted the future energy consumption for the period 2014-2020. This is presented in Table 6.5. Using this data a simple mathematical model using MATLAB is obtained to predict future energy requirement until 2030. A fourth order polynomial relationship was obtained (see Appendix 2) between the energy requirements (ER) and the year for the period 1991 to 2030 and given in the following equation:

$$ER\ [million\ kWh] = \frac{9.86\ (year-2006)^4}{100} + 4.99\ (year-2006)^3 + 78.2\ (year-2006)^2 + 2382\ (year-2006) + 45517 \quad (6.1)$$

Figure **6.5** shows the MEW data and the data obtained from the equation. As shown in this figure, electrical energy required for the year 2030 will be 250 million MWh if the energy requirement follows the same pattern as it was over last two decades. This is roughly four-fold higher than current level and will have serious impacts on Kuwait's economy and environment. These issues will be addressed in the following sections of this research.

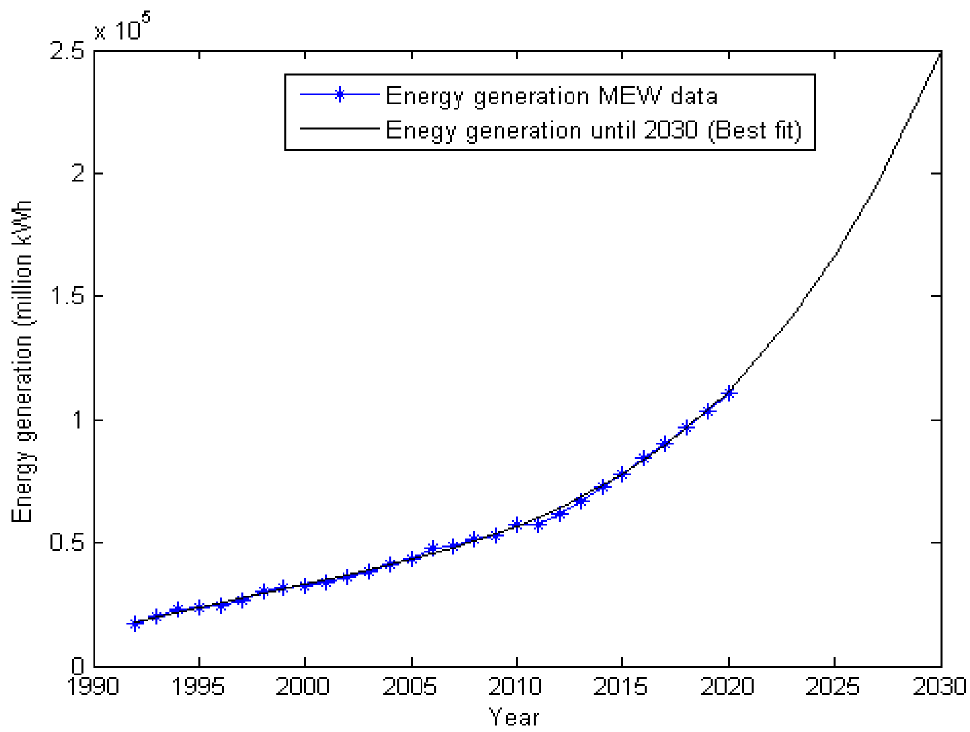

Figure 6.5: Actual and the predicted energy generation, 1992 to 2030

6.6.2 Estimating the Energy Generated by Al-Shagaya Project

As mentioned earlier in this chapter, Al-Shagaya Project will generate 70 MW in phase one; 10 MW PV, 10 MW wind, and 50 CSP. To-date there is no clear information on how much energy will be generated from each technology in the second and third phases. With a simple calculation we can find out the percentage of energy each type of technology will generate in phase one, and it is assumed the same percentages will apply (proportionally) in the subsequent phases. Table 6.5 presents the percentages and projected energy that will be generated from each technology during the period 2016-2030.

Table 6.5: Projected energy generated from RE in MW for the period 2016-2030

Year	Installed capacity (MW)	PV (MW) 14.3%	Wind (MW) 14.3%	CSP (MW) 71.4%
2016	70	10	10	50
2025	930	133	133	664
2030	1000	143	143	714

6.6.3 Energy from Solar (PV and CSV)

The amount of energy produced by solar panels (PV as well as CVS) is determined by two factors: the capacity of the solar panels and the amount of sunlight available. The amount of energy generated can be calculated using the following equation:

$$\text{Amount of energy [kWh]} = \text{capacity [kW]} \times \text{hours of sunshine per day [h]} = 1000 * \text{capacity [MW]} \times \text{hours of sunshine per day [h]} \quad (6.2)$$

In Kuwait it is very reasonable to assume that on average there is 6.5 hours of good sunshine available every day, as mentioned in Table 3.2. The above equation can be re-written to calculate amount of energy produced per year as below:

$$\text{Amount of energy per year [kWh]} = \text{capacity [MW]} \times 6.5 \times 365 \times 1000$$

$$\text{Amount of energy per year [kWh]} = 2372500 \times \text{capacity [MW]} \quad (6.3)$$

6.6.4 Energy from Wind

The wind energy can also be calculated in a similar way to solar energy calculations and equation (6.2) now becomes;

$$\text{Amount of energy [kWh]} = \text{capacity [kW]} \times \text{hours of full-load wind [h]} = 1000 * \text{capacity [MW]} \times \text{hours of full-load wind per day} \quad (6.4)$$

According to the data presented in Table 3.4, there is 1605 hours of full-load wind in Kuwait; using this figure, the total energy produced by wind energy can be calculated as:

$$\text{Amount of energy per year [kWh]} = \text{capacity [MW]} \times 1605 \times 1000 = 1605000 \times \text{capacity [MW]} \quad (6.5)$$

6.6.5 Projected Energy Generation by Al-Shagaya Project

Now using equations (6.3) and (6.4), energy generated per year by Al-Shagaya Project can be estimated. Table 6.6 presents the energy generated per year by RE in each phase. Column 4 presents the total energy generated (PV, wind and CSP). Though the capacity of PV and wind are same, the energy produced by solar is greater; this shows that solar seems more effective than wind in Kuwait.

Table 6.6: The projected energy generation by PV, CSV and wind in each phase of Al-Shagaya Project

Year	Energy generated from PV (millions kWh)	Energy generated from wind (millions kWh)	Energy generated from CSP (millions kWh)	Energy generated (millions kWh)
2016	24	16	119	159
2025	319	214	1575	2108
2030	339	230	1694	2263

Table 6.7: Projected energy share by traditional and RE

Year	Energy required* (million kWh) - Eq (5.1)	Renewable Al-Shagaya (million kWh) Table 5.5	Energy needed by traditional (million kWh)	Traditional Energy (%)	RE (%)
2011	57489	0	57489	100	0
2016	84423	159	84264	99.8	0.2
2025	166090	2267	163823	98.6	1.4
2030	249420	4530	244890	98.2	1.8

Table 6.7 compares the future traditional energy production by MEW and RE generated by Al-Shagaya Project. The first column gives the required energy as predicted by equation (6.1), the second column gives the energy that will be produced by Al-Shagaya Project and third column is the energy that will be required by the traditional methods of energy generation if RE is presented. The last two columns show the percentage of energy production by traditional and renewable methods. This clearly shows that there is a small portion of reduction in traditional method and implies that to have a real impact there is a lot to be done in terms of promoting RE. The gap between the required traditional energy and the forecasted energy production by Al-Shagaya Project can be understood in Figure 6.6.

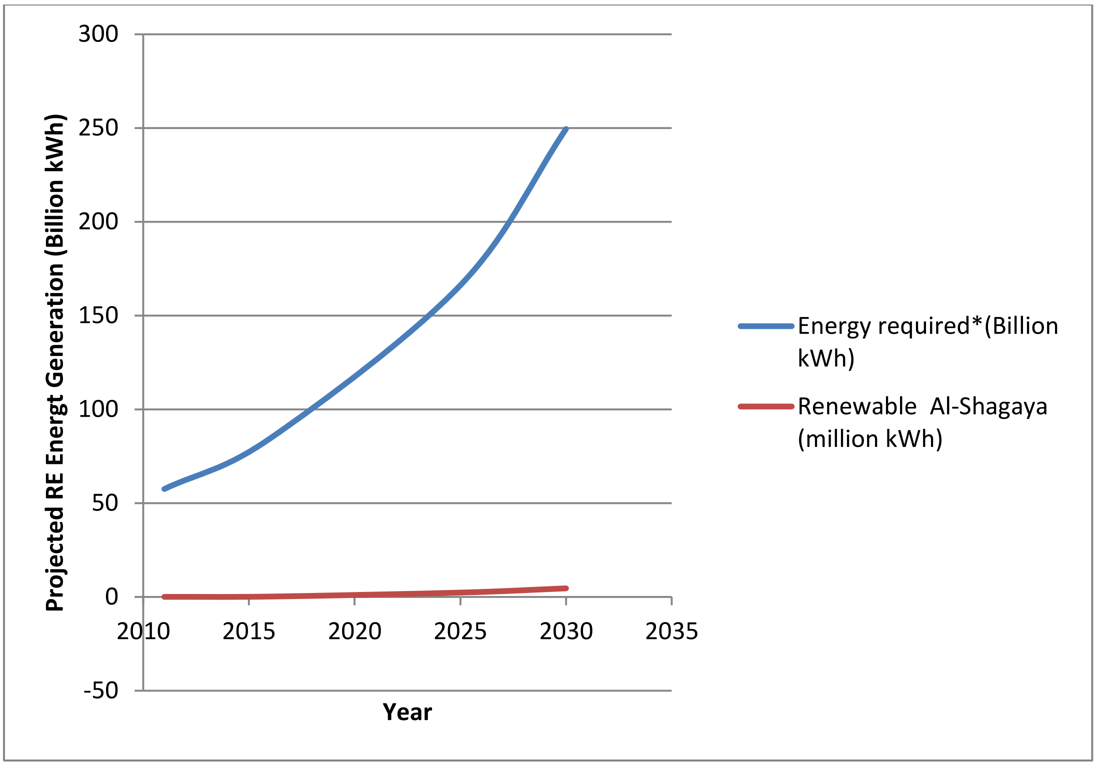

Figure 6.6: Energy required and forecasted energy production by RE

6.7 Predicted Cost of Energy Generated by MEW and by Al-Shagaya Project

The cost of traditional energy per kWh is always increasing because of increasing demand for electricity, inflation and increased structural price of fossil fuels due to diminishment of reserves and increasing difficulty of extraction. However, the cost of solar energy per kWh is predicted to be decreasing as technology advances. Therefore, a simple but a crucial analysis is carried out to find out whether Kuwait will gain any economic benefit by adapting RE.

6.7.1 Cost of Traditional Energy Generated by MEW

Using the data presented from the Statistic Department and Information Centre in MEW for the period 2004-2011, the cost of traditional energy per kWh is calculated and presented in Table 6.8, the last column of which presents the unit cost in fills using:

$$\text{Cost [fills]} = \frac{1000\times \text{Total cost[KD]}}{\text{Total electricity generated [kWh]}} \tag{6.6}$$

Note that one Kuwaiti Dinar (KD)=1000 fills.

Table 6.8: Traditional energy production: amount of energy, total cost and unit cost

Year	Total electricity generated (million kWh)	Total cost of energy generated (KD)	Cost per kWh (fills)
2004	41256761	531997450	12.9
2005	43734033	856740888	19.6
2006	47604822	1063346553	22.3
2007	48753707	1229159254	25.2
2008	51748909	1779600786	34.4
2009	53215847	1397814160	26.3
2010	57082798	1654888837	29.0
2011	57488755	2422123152	42.1

From the cost calculated in Table 6.8 it is now possible to predict the cost in future. First, the trend line of the cost is obtained using the best-fit tool available in MATLAB. The equation of the trend line of the cost from which future cost is extrapolated is:

$$Cost\ of\ unit\ cost\ [fills] = 3.2303 * Year - 6458.3 \tag{6.7}$$

The unit cost of electricity for the period from 2004 to 2011 is shown in Figure 6.7 along with the linear trend line. As can be seen in this figure, the cost during this period fluctuates very much and the reasons for the spikes are the fluctuation of oil price such as in 2008 and 2009. However, for the purpose of the cost analysis, it is taken only the major trend of the electricity cost using the linear trend line. This is because the future unexpected events cannot be predictable. From this linear trend line (equation 6.7), the future electricity unit cost is extrapolated an shown in Table 6.9.

6.7.2 Calculating the Future RE Cost for Al-Shagaya Project

This cost analysis considers solar, wind and concentrating solar power technology costs compared to those of traditional energy. This is the first study to calculate future RE costs in Kuwait. It uses data from the IEA [19].

The Levelised Cost of Energy (LCOE) is used in the cost analysis comparison of RE and TR to determine generation costs based on forecasting the average costs over the entire project operating life in terms of fuel, operations and maintenance (O&M) costs. Specific cost factors can be incorporated in this analytical framework, such as carbon prices, contingency and decommissioning. LOCE is the most widely accepted tool for comparing power generation costs in design and policy discussions [19].

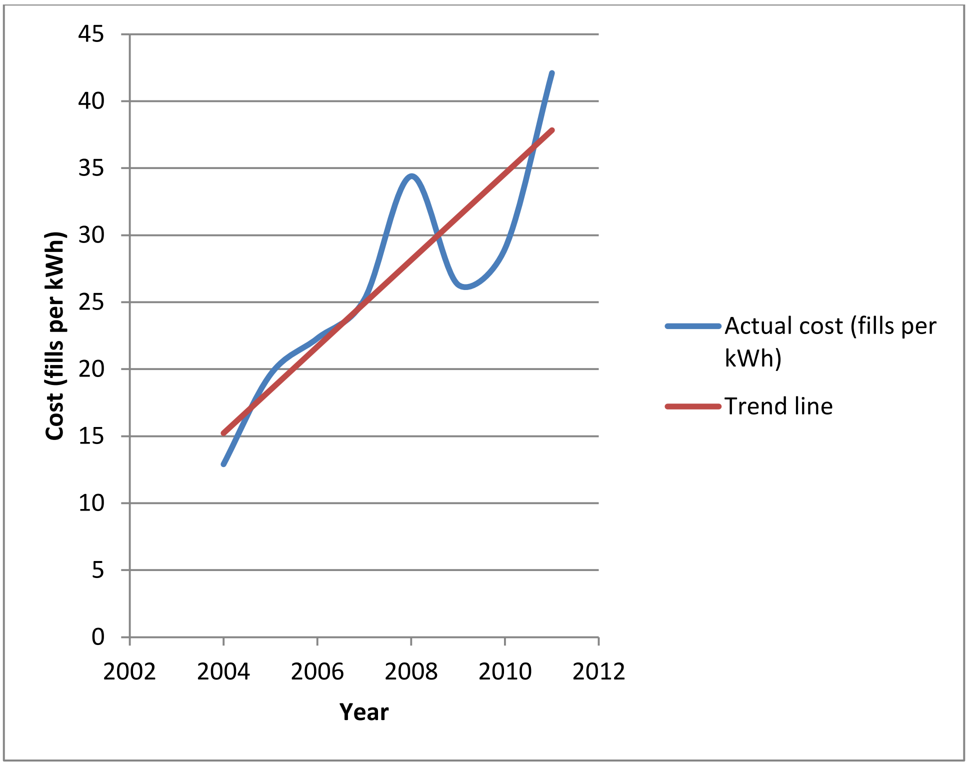

Figure 6.7: Cost of electricity and its trend line

Table 6.9: Predicted cost per kWh

Year	Cost of tradition energy per kWh (fills) – predicted $\mathbf{3.2303 \times Year - 6458.3}$
2013	44.2939
2014	47.5242
2015	50.7545
2016	53.9848
2017	57.2151
2018	60.4454
2019	63.6757
2020	66.9060
2021	70.1363
2022	73.3666
2023	76.5969
2024	79.8272
2025	83.0575
2026	86.2878
2027	89.5181
2028	92.7484
2029	95.9787
2030	99.2090

6.7.3 Photovoltaic Energy Technology

Global photovoltaic installed capacity increased by 40% during the 2000s, and PV module prices correspondingly decreased by 22% for each doubling of cumulative capacity [19] (related to supply bottlenecks and market dynamics from 2003-2008).

Increased private and state investment increases cost efficiencies associated with scale, supply chains and production capacity. Figure 6.8 below presents the projected LCOD cost for solar energy technology in US per (MWh) from 2010-2030.

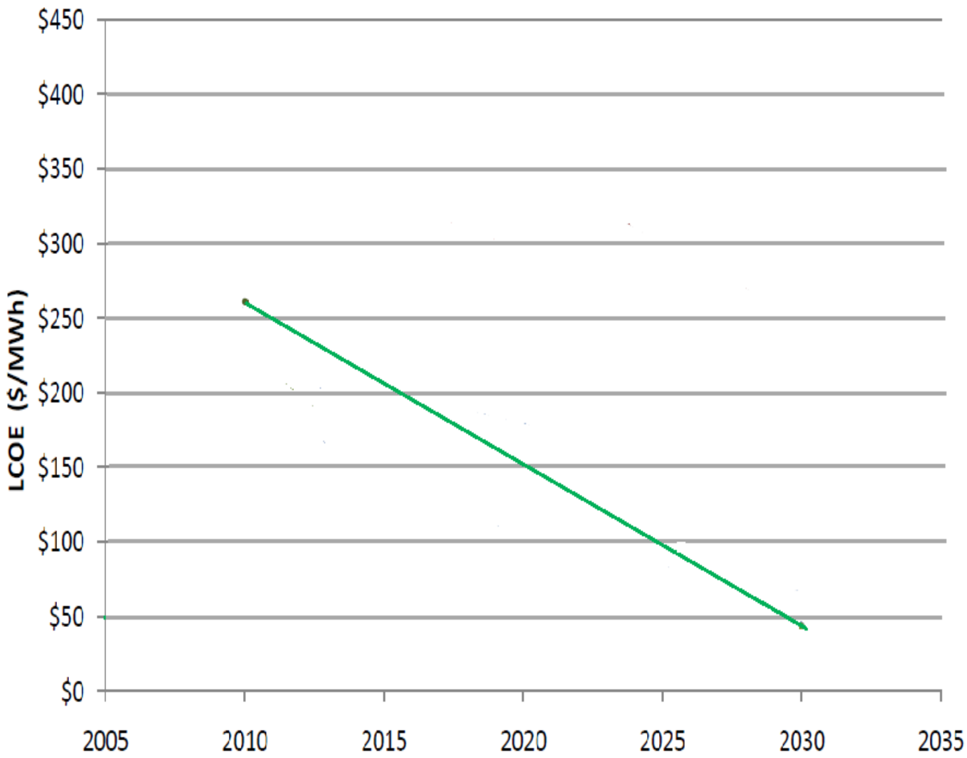

Figure 6.8: Solar photovoltaic cost projections LCOE ($/MWh) 2010-2030 [19]

6.7.4 Wind Energy Technology

The growth in wind RE increased significantly during the 2000s, reflecting its relatively cheap installation costs, with installed capacity doubling every three years. Costs have remained stagnant (without significant reductions) due to supply chain bottlenecks and large demand, although increasing automation in the manufacture and installation of turbines is causing costs to continue along historic learning rates. Turbine design has improved, resulting in greater efficiency [19]. Figure 6.9 below presents the projected LCOD cost for wind energy technology in the US (MWh) from 2010-2030.

6.7.5 Concentrating Solar Thermal Energy Technology

CSP technology is newer than alternative RES but it offers significant financial savings from technical economies of scale and technical improvements [19]. Figure

6.10 presents the projected LCOD cost for Concentrating Solar Thermal Energy Technology in the US per (MWh) from 2010-2030.

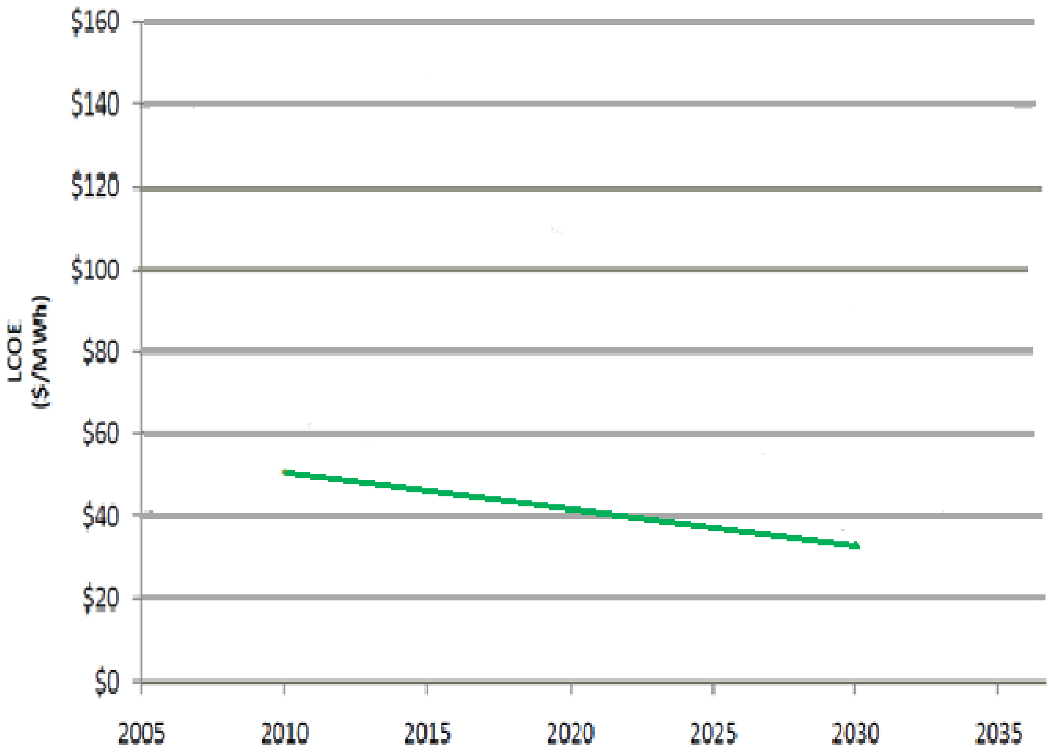

Figure 6.9: Wind power cost projections LCOE from 2010-2030 [19]

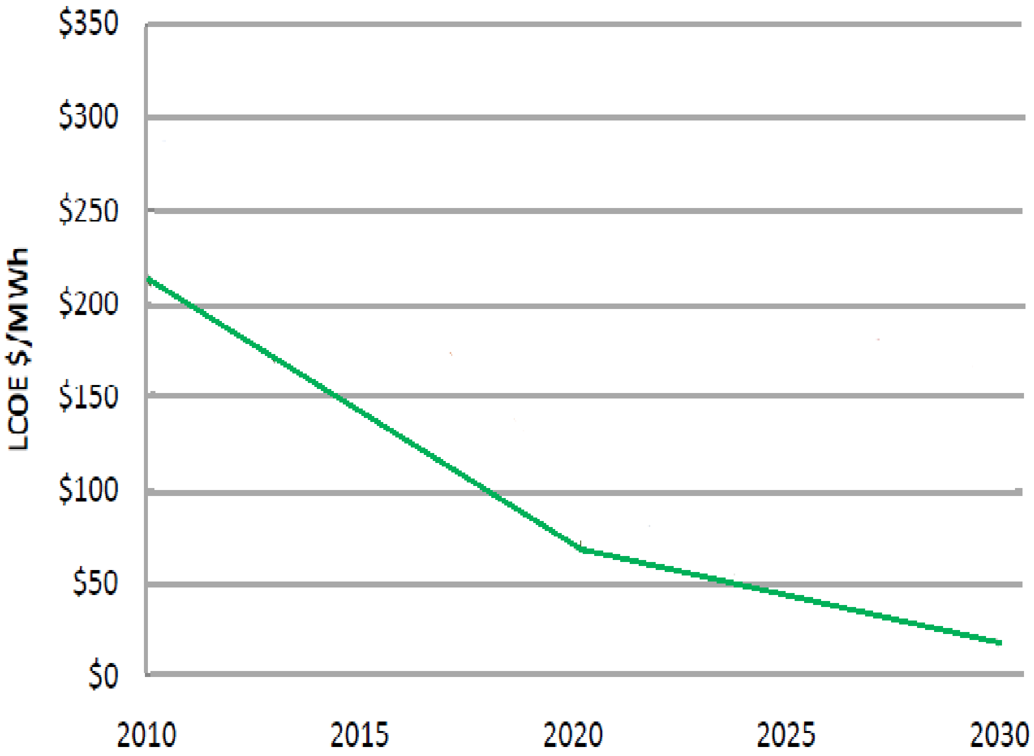

Figure 6.10: CSP cost projections LCOE from 2010-2030 [19]

From Figures 6.8-6.10, an estimation of the future cost of PV, wind and CSP can be devised as shown in Table 6.10. The cost in Kuwaiti fills is presented in the fifth, sixth and seventh columns of this table. In addition, the future cost of TRE from Table 6.9 is presented in the last column for comparison.

Table 6.10: Future cost of RE

	The cost of energy per kWh (US$)			The cost of energy per kWh (fills)			
Year	PV	Wind	CSP	PV	Wind	CSP	TRE
2016	0.19	0.045	0.14	57	13.5	42	54
2025	0.1	0.039	0.04	30	11.7	12	67
2030	0.04	0.035	0.02	12	10.5	6	99

Figure 6.11 shows the future RE cost of PV, wind and CSP for three phases along with the future cost of TRE. It can be seen that solar costs are expected to decrease very rapidly whereas wind remains steady; however, CSP is expected to achieve greatest cost efficiency. TRE production is the only source expected to increase in price.

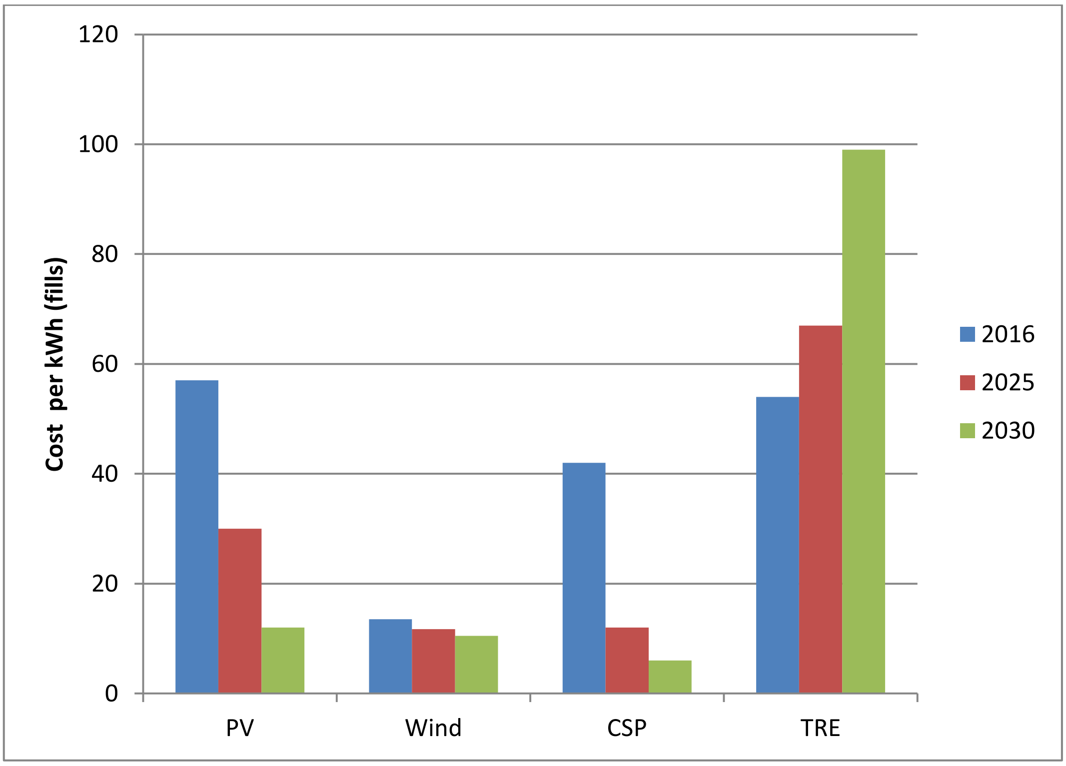

Figure 6.11: Future cost for renewable energy technologies for each of three phases

6.8 Impact on CO_2 Emissions

Using the data on CO_2 in Kuwait for the period 1971-2010 Mundi data [177] (Table 6.4), it is now possible to predict the future CO_2 emissions (CO_2_E) in Kuwait, assuming all other factors are remaining constant. A best-fit formula for these data is obtained using MATLAB best fit tool and the equation is a third order polynomial with centre shifted as given below:

$$CO_2\_E\ [\text{million metric tons}] = \frac{1.76(\text{Year}-1990)^3}{1000} + \frac{3.94(\text{Year}-1990)^2}{100} + \frac{7.78(\text{Year}-1990)}{10} + 17.9 \quad (6.8)$$

The actual and the predicted (using equation 5.8) CO_2 emissions for the period up to 2030 are shown in Figure 6.12. In this graph, the sudden drop in CO_2 emissions during the early 1990s was due to the Gulf War, during which reduced amounts of energy were generated. According to this prediction, CO_2 emissions by 2030 will be more than four times the current level, which warrants serious consideration.

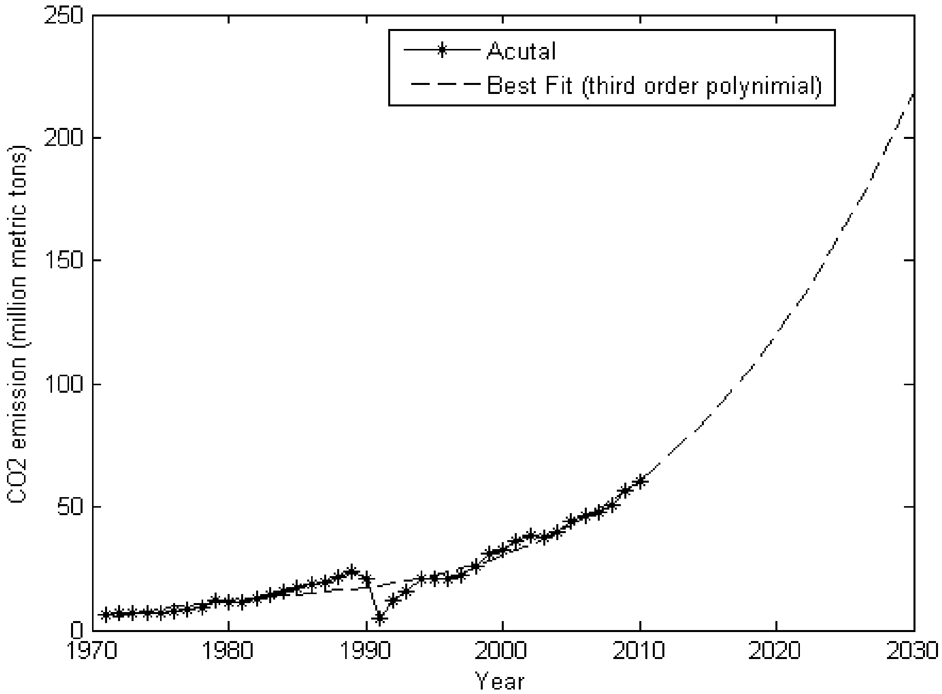

Figure 6.12: CO_2 emissions (actual and predicted)

As mentioned earlier, the energy proportion from the Al-Shagaya Project by 2030 will only comprise 2.05% of energy required; the reduction in CO_2 in 2030 will therefore only be by 2.05% compared to without Al-Shagaya, and overall the CO_2 emissions will more than double from current levels. This represents a manifest failure of planning and strategies to seriously diversify Kuwait's sources and use of energy. Thus, it is very important for the Kuwaiti government to take immediate and serious steps in order to reduce CO_2 emissions by moving its electricity generation from traditional to RE.

6.9 Investigation of a New Method to Implement RE

Having investigated the current RE project in place, it is very clear that Kuwait is not going to make any significant economic benefits in terms of energy production and CO_2 emission reduction. Therefore, it is very essential to seriously promote more RE installation in Kuwait in addition to the Al-Shagaya Project, which according to current trends is no more than a token effort, in order to make a significant economic return and sensible CO_2 reduction. In this section, a simple but effective scenario is investigated and the cost impact and respective CO_2 emission reduction is calculated. The proposed scheme is such that the percentage of traditional energy production (TRE) method is linearly decreased to 0% from current level (100%), and in the same time the RE percentage linearly increases to 100% from the current level (0%) by 2030. This scenario is referred as a linear changeover, as shown in Figure 6.13.

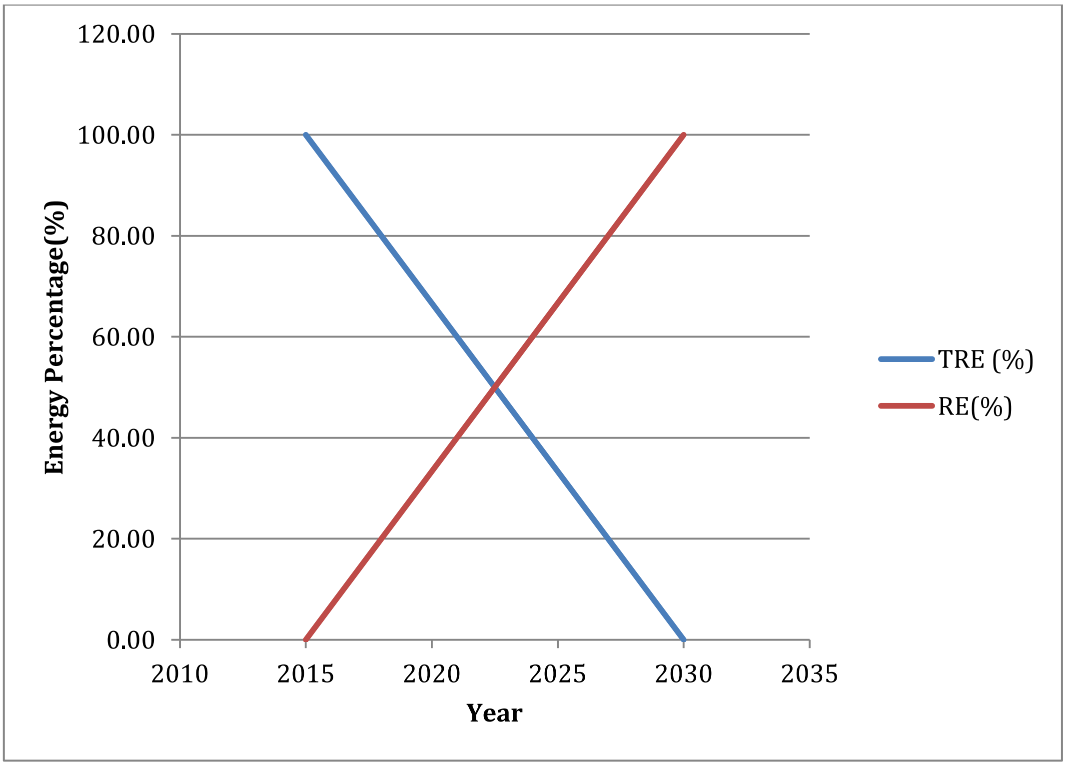

Figure 6.13: The proposed linear changeover scheme

Table 6.11 presents all the required information for linear changeover scheme. Column 2 presents the required total energy in Kuwait as predicted by MEW (equation (1)) and column 3 is the percentage of the required energy to be produced by TRE, which shows a linear reduction from 100% in 2015 to 0% in 2030. The energy (million kWh) to be produced by TRE and RE are presented in columns 4 and 5 respectively. Columns 6 and 7 give the cost per kWh for both TRE and RE, which are calculated from the prediction made previously (equations (5) and (6) respectively). From these figures (energy produced and cost per kWh), the total cost for TRE and RE are separately calculated and presented in columns 8 and 9, and the final overall cost is presented in the last column.

Though percentage energy of TRE and RE linearly decrease and increase respectively, the actual energy generated will be not be linear, as the future requirement is not constant but increasing, as given in column 2 in Table 6.11 and also shown in Figure 6.13. In mid-2022, the energy share of TRE and RE will be the same.

Although, the cost of all the three RE methods are decreasing in from 2016-2030 due to technology improvement and economic of scale (Figure 6.11), wind and CSP looks promising in future. The future cost of CSP will decrease dramatically from its current relatively high price. However, CV cost does not decrease as fast as CSP. Furthermore the current cost of wind is much lower than CSP and CV, though it does not show a big decrease over the time. Therefore, using 50% of wind and 50% of CSP technology will be considered as the RE technology for the proposed linear changeover scenario.

As explained previously, the cost of TRE per kWh will be increasing in forthcoming years whereas it will be decreasing for RE. Figure 6.14 shows the total cost of the energy production for both TRE and RE, overall cost (TRE+RE) and the total cost of the RE in the case if TRE is only used for electricity production (TRE only). The cost of TRE increases until 2023, and then it decreases to zero in 2030.

The total cost depends on the cost per kWh as well as the amount of energy produced. In the case of TRE, the cost per kWh is increasing whereas the amount of energy produced is decreasing; however, until 2023, the first one dominates and reverses afterwards. On other hand, in the case of RE, the cost per kWh is decreasing but the amount of energy is increasing; however the overall cost linearly increases for the period considered here. The overall cost increases until 2025, and then it decreases continuously.

If only TRE is being generated, the cost would be dramatically higher, as shown in blue line in Figure 6.15. The percentage economic benefit is calculated using the following equation:

$$EconomicBenefit\ (\%) = \frac{CostofTREonly - Costofproposedscheme}{CostofTREonly} \times 100$$

(6.9)

Table 6.12 presents the economic benefit in terms of million KD and percentage for the period 2015 to 2030 and percentage economic benefit is also presented in Figure 6.16. The linear changeover scheme shows a clear economic advantage with an ultimate saving of 92%.

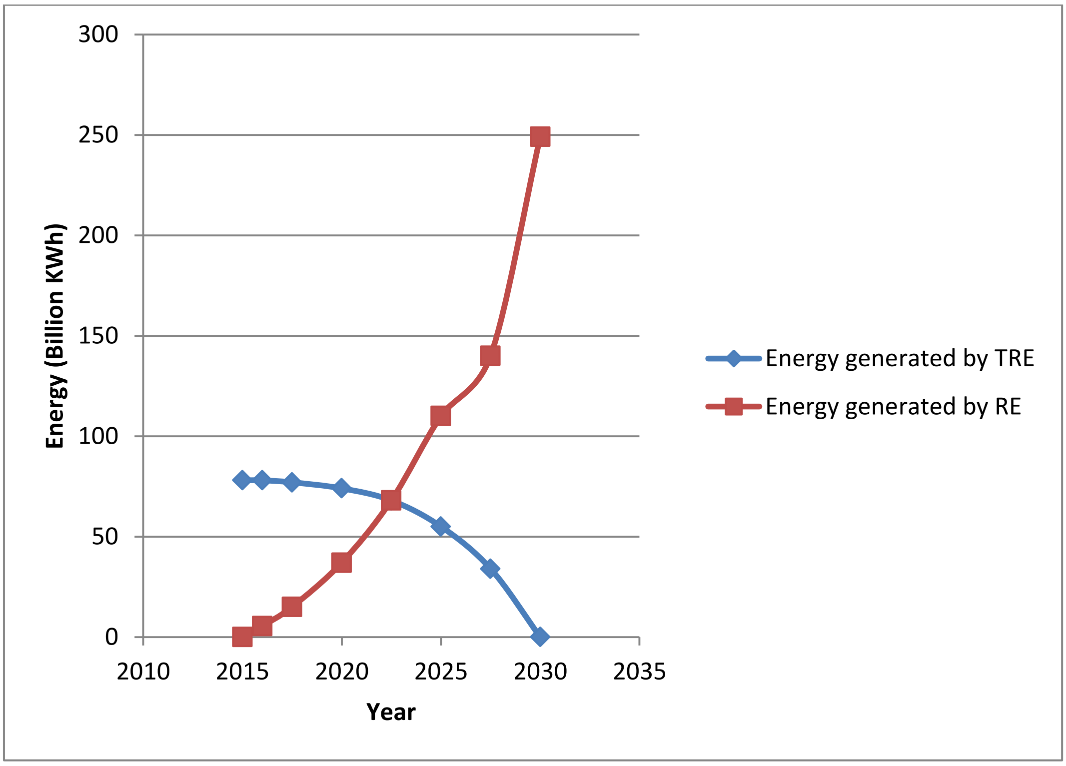

Figure 6.14: Energy produced by TRE and RE for linear changeover scheme

Table 6.11: The projected energy amount and cost for both TR and RE

Year	Energy required (million kWh)	TRE (%)	TRE (million kWh)	RE (million kWh)		Cost per kWh (fills)			Total cost (Billion KD)		
				Wind	CSP	TRE	wind	CSP	TRE	RE	Total
2015	77580	100	77580	0	0	51	0	0	3.96	0.00	3.96
2016	83140	93	77320	2910	2910	54	13.5	42	4.18	0.16	4.34
2017.5	92570	83	76833	7868.5	7868.5	59	12.6	33	4.53	0.36	4.89
2020	111680	67	74826	18427	18427	67	12.3	21	5.01	0.61	5.63
2022.5	135840	50	67920	33960	33960	75	12	18	5.09	1.02	6.11
2025	166090	33	54810	55640	55640	83	11.7	12	4.55	1.32	5.87
2027.5	203540	17	34602	84469	84469	91	11.4	7.5	3.15	1.60	4.75
2030	249420	0	0	124710	124710	99	10.5	6	0.00	2.06	2.06

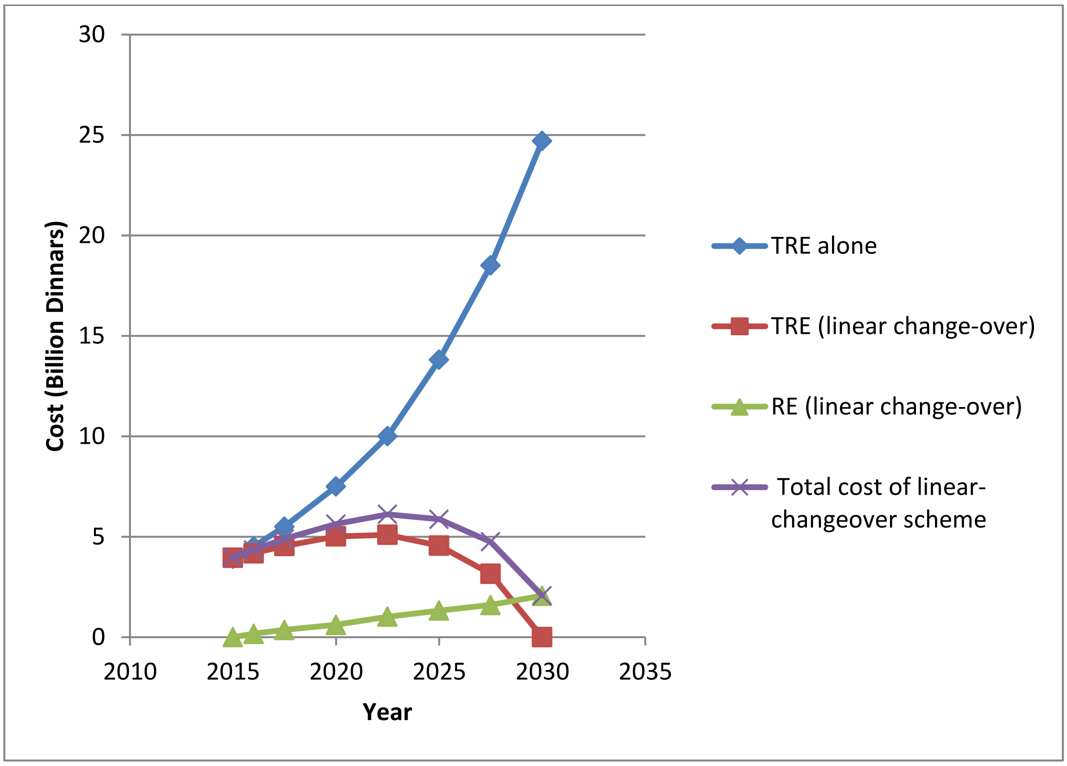

Figure 6.15: Cost of TRE, RE and total cost in linear changeover scheme

Table 6.12: Projected cost of TRE in Million KD until 2030

Year	Cost (Billion KD)		Economic Benefit	
	Linear changeover scheme	TRE only	million KD	%
2015	3.96	3.96	0	0
2016	4.34	4.49	0.15	3
2017.5	4.89	5.46	0.57	10
2020	5.63	7.48	1.85	25
2022.5	6.11	10.19	4.08	40
2025	5.87	13.79	7.92	57
2027.5	4.75	18.52	13.77	74
2030	2.06	24.69	22.63	92

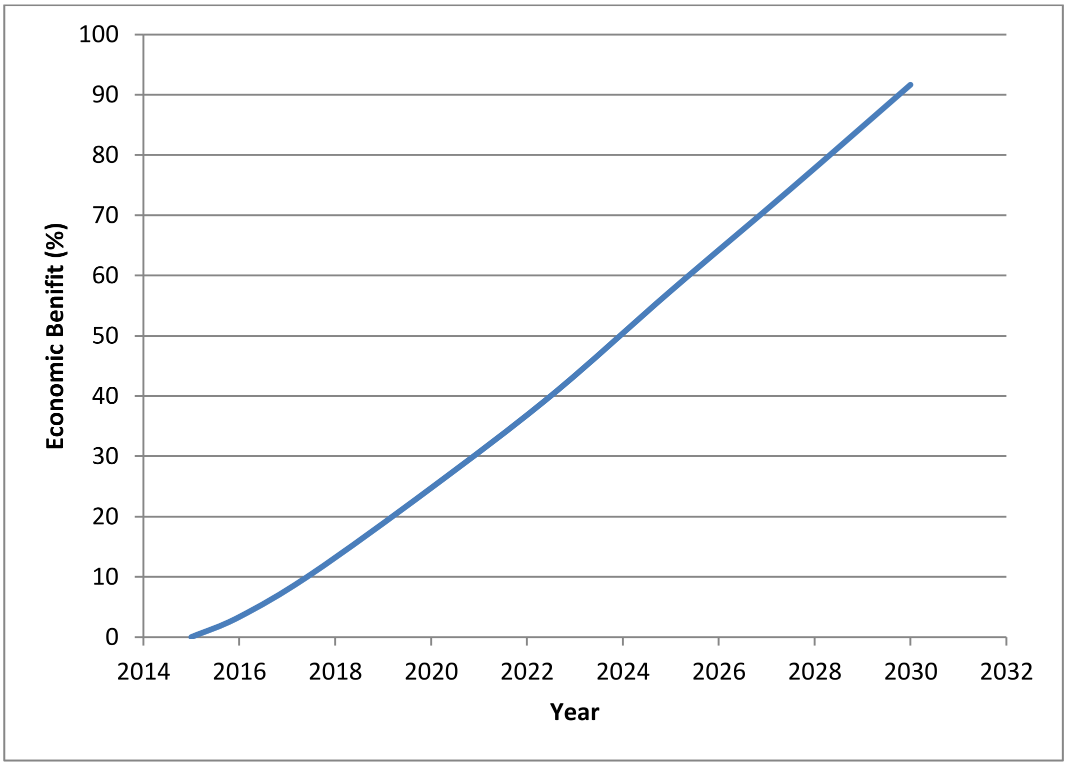

Figure 6.16: Economic benefit in linear changeover scheme

6.10 Environmental Benefits

As mentioned before using equation 6.8, CO_2 emission from electricity generation from MEW in 3030 will be more than four times the current level (Figure 6.12). According to the proposed linear changeover scheme, CO_2 will be reduce gradually to 0% in 2030. Again it will not follow a linear path, rather follow the amount of electricity generated by TRE. Table 6.13 presents the effect of the proposed linear changeover scheme on the overall CO_2 emission per million metric tons. Column 1 shows the required energy generated from TRE only scheme, column 2 shows the projected TRE with the proposed linear changeover scheme, column 5 shows the amount of CO_2 emission as a result of generating energy from TRE only and finally column 6 shows the amount of CO_2 emission reduced as a result of using the proposed linear changeover scheme.

Figure 6.17 shows the CO_2 emission with the linear changeover scheme as well as TRE only scheme. It clearly shows the potential reduction of CO_2 as a result of linear changeover scheme.

Table 6.13: The effect of proposed linear changeover scheme on CO_2 emission

Year	Energy produced (million kWh)			CO2 emission (million metric tons)	
	TRE only	TRE with the proposed scenario	TR % change	CO2 emission from TRE only	CO2 emission from TRE with the proposed scenario
2015	77580	77580	0	89.475	89.475
2016	83140	77320	7.000241	95.69616	88.9972
2017.5	92570	76833	17.00011	105.6938	87.7257
2020	111680	74826	32.99964	124.22	83.22784
2022.5	135840	67920	50	145.2188	72.60938
2025	166090	54810	66.99982	168.855	55.72245
2027.5	203540	34602	82.9999	195.2938	33.20013
2030	249420	0	100	224.7	0

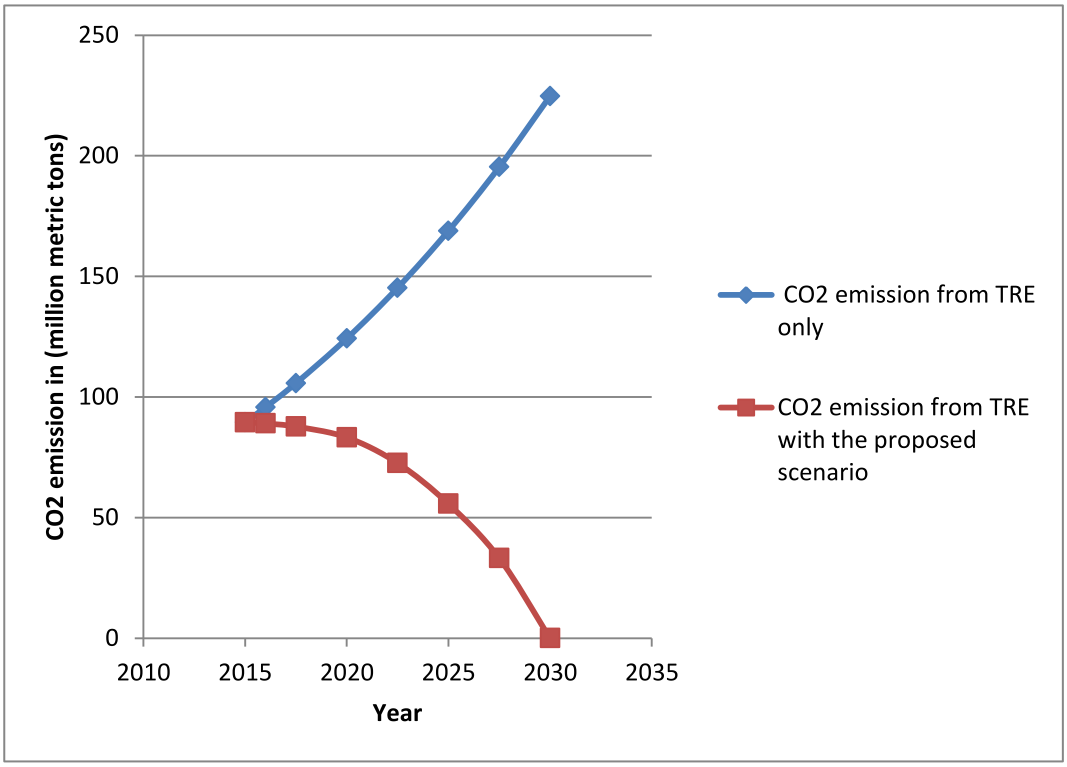

Figure 6.17: CO_2 emissions with and without the proposed changeover scheme

6.11 Cost Analysis Summary

The fundamental reason behind adopting any renewable energy for any society is first to decrease the burden of high traditional energy costs and secondly to reduce CO_2 emissions in the environment. Al-Shagaya is innovative renewable energy project sponsored by Kuwait Institute for Scientific Research. The main goal of the project is to balance the energy needs when the demand is at the highest, for example in summer, reduce the traditional energy costs and to reduce CO_2 emissions. Although the Project was targeted to contribute up to 15% of Kuwait's total power production by 2030, the cost analysis presented in this chapter reveals that the project will be able to generate only 2% of the energy required by 2030. As a result, the project will only reduce CO_2 levels by 2% relative to total TRE production (i.e. if there were no RES in the power composition), while the net emissions will increase substantially.

A linear changeover scheme was presented in this cost analysis. This scenario basically assumes that the percentage of TRE method is linearly decreased to 0% from the current level (100%), and in the meantime the RE percentage linearly increases to 100% from the current level (0%) by 2030. As a result, the reduction in the cost of energy generation will be 92% and the CO_2 emissions will decline to zero within the same timeframe.

CHAPTER 7: CONCLUSION, RECOMMENDATIONS AND FUTURE WORK

7.1 Conclusion

For decades, traditional sources of energy (fossil fuels) have maintained their position as the leading source of energy worldwide. This source, however, comes with negative externalities, such as dangerous levels of pollutants that degrade the quality of life, not only in largely industrious countries, but all around the globe, bringing about climate change, health hazards, and other devastating outputs. The international community has begun taking steps towards resolving this global issue. This has led to an incorporation of strategic thinking in regards to alternative sources of energy amongst the members of the international community.

The general attitude within the international community realizes that GCC countries are among the leading players impeding progress in reducing the human carbon footprint. Furthermore, all six GCC countries are among the top 25 biggest emitters of carbon dioxide per capita, with UAE and Kuwait leading the others. Studies revealed that the carbon dioxide released in Kuwait is among the highest in the world (almost 40 million tons per day) as a result of electricity and water desalination, expected to rise to 70 million tons per day (a 75% increase) by 2030.

The IPCC urged the world to reduce GHG emissions by at least 60-70% in order to stabilize the atmosphere and limit the inevitable harmful effects to the ecological and other biophysical systems. It is generally agreed throughout the literature that the oil era will be over before the end of this century, there is now no other solution but to seriously search for other sources of energy that are renewable and friendly to the environment such as solar, wind, geothermal, hydrogen, and bio energy in the production of electricity.

The literature on the GCC countries shows that geographically, these countries make wind and solar RE a strong and available commodity, and the possible challenges of dust (in the case of solar) or light and noise changes (in the case of wind) have been solved in the cases of these applications being used internationally. Further, the literature on GCC countries also shows that Kuwait, at current usage rates of nonrenewable fuels, will reach an unsustainable percentage of the national budget, with the costs of national subsidies and of the available fossil fuel supply posing great difficulties. The literature shows that many people do not know the costs, whether financial or natural resource-based, because such costs are hidden by subsidized fuel prices. The literature identified that in the GCC countries, despite having the potential for solar and wind energies, RES face various economic, technical and social challenges, such as:

1. A lack of political interest, no clear strategies for RE, the absence of the policy legislation, plus there is an absence of a relative legal framework and agreements for the promotion of RE.
2. No visible RE targets to attract developers and financial institutions.
3. The market lacks of commercial skill, scientific knowledge and experience.
4. The low price fossil fuels and high cost of RE, entrenched by existing governmental subsidies for oil and electricity that do not exist for RE.
5. The dust, heat and humidity comprise major environmental hindrances to the efficiency of such technology to generate energy.
6. The on-going investments in oil exploration and refining.
7. The failure of the market to value the public benefits of renewable and the lack of public awareness.

The analysis of the questionnaire acknowledged that most participants doubted that the Kuwaiti government is serious or reliable about investing in RE as an alternative source of energy due to lack of policy and legislations, lack of management and technical skilled personnel, RETs costs being considerably high (which prevent consumers adoption), lack of local institutions research and information, and lack of RET education college programs and curriculums. Most of them support the idea of allowing the private sector to invest in RES and RET.

All participants were environmentally conscious and convinced that most pollutants released into the atmosphere came from fossil fuels. All participants appeared to have a high level of support for renewable energy, especially solar and wind power generation, due to their awareness of knowledge that wind and solar are resources available in nature that could be utilized to generate electricity. Nearly all participants agreed to pay more for traditional sources of energy to promote the development of renewable energy, and all of them supported powering facilities with clean RE sources.

Although positive attitudes of the use of RET were high across all the questionnaire participants, there was a wide difference in awareness of own knowledge regarding the RET and its associated environmental problems, such as noise and visual intrusion. Almost all participants agree on the need for environment laws and RE legislation, and the benefits of allowing the private sector to invest in RE and breaking the government monopoly of energy. All agree that RE suffers from lack of social acceptance and awareness among Kuwaitis, and that Kuwait needs to establish energy research and local centres associated with global energy centres for data information in addition to educational programs and the inclusion of RE in educational curriculums.

A large majority of the group participants believe that Kuwaiti government should support the pilot demonstration projects for every type of renewable energy sources as ‘a way of looking after our future’.

Al-Shagaya Project is the most ambitious endeavour undertaken by the Kuwaiti government for solar and wind power. Although the project was targeted to contribute up to 15% of Kuwait’s total power production by 2030, It is evident from the analysis presented in this research that it is only capable of generating 2% of the required total energy needed by 2030; furthermore, the CO_2 emissions will be reduced by the same percentage, while actual emissions in 2030 are predicted to be more than double the current level. A smooth changeover from TRE to RE was proposed by this research such that a large-scale investment in RE and a linear changeover model would reduce CO_2 emissions from electricity generation to zero by 2030, and save 92% on costs compared to traditional energy sources.

7.2 Recommendations

Throughout the following recommendations can be inferred from the foregoing review of the literature, the results of the questionnaires, and the cost analysis for better economic benefits and facilitate better deployment of RE in the GCC and Kuwait specifically. Because of the fact that the questionnaires were constructed based on studies that were discussed in the literature review, the following recommendations were driven from the knowledge attained the review of literature as well as the analysis of the questionnaires. In order for the GCC countries to adopt RET and overcome their related barriers, GCC countries should follow the recommendations presented below.

7.2.1 Literature Review and Questionnaire Recommendations

1. Develop a long-term renewable energy policy with a clear vision, good leadership, and financial support to be able to build strong legislations to motivate the development of renewable energy sources, to regulate manipulation and operations throughout the process and overcome the barriers that prevent their production.

2. Locate all renewable energy sources programs and development around the world and make the information available on industry markets programs including technology, supportive infrastructure and financing mechanisms open to the public, businesses and other stakeholders to attract the interest of entrepreneurs in driving adoption. In addition, involve international collaboration on the development and deployment of renewable energy technologies and assess project achievements.

3. Establish legislative policies to encourage businesses and stakeholders to invest in renewable energy technologies and generators.

4. Raise general public awareness and perspectives of the important benefits and potential of renewable energy. Adopt a comprehensive awareness-raising program on renewable energy sources and its benefits on the environment, to encourage public appreciation, acceptance and support the adaption of renewable energy.

5. Develop academic programs in colleges and systematic curricula in technical schools for renewable energy. Kuwait University and Public Authority for applied Education and Tanning offer petroleum engineering programs and conventional energy technology both graduate and postgraduate levels; it is crucial to start building academic and training programs to have sufficient professionals and trained technical personnel to be able to formulate policy and legislation, design, implement, and maintain renewable energy systems. These programs will help improve R&D activities in the technological implementation, economic, investment and other social aspects of renewable energy.

6. Invest in both solar and wind renewable energy technologies and provide the public, businesses and stakeholders detailed assessment of the availability of both energy technologies and their development. In addition, search for the best solutions to overcome their barriers of dust, humidity and heat and allow businesses and other stakeholders to collaborate in making decisions on trading and technology implementation.

7. Build strategies to reflect the environment costs and benefits of reducing pollution and cut GHG emissions to the atmosphere and establish government subsidies for RE sources to offer financial support. Additionally, put a price on (i.e. tax) pollution, reduce externalities and provide a more competitive policy for alternative energy producers.

7.2.2 Cost Analysis Recommendations

The following recommendations were driven from the cost analysis calculations. The Kuwaiti government should:

1. Consider seriously investing more money and resources to implement more renewable energy sources in addition to Al-Shagaya Project, which has a negligible practical impact.

2. Work on finding ways to reduce CO_2 emissions significantly (since Al-Shagaya Project can only reduce them by 2%).

3. Consider more solar-based RE in comparison to wind because of Kuwait's superlative suitability for solar energy harvesting.

7.3 Renewable Energy Implementation Roadmap Model

The implementation roadmap (Figure 7.1) model has been extracted from this research to highlight the important procedures that have to be followed in order to implement an efficient renewable energy model in the GCC. The methodology used to come up with the components of this model (namely the literature review, questionnaire, and the cost analysis) shed light on the crucial components in the implementation of renewable energy.

In the literature review, the author investigated the negative impacts of fossil fuels, and the potential for solar and wind energy within the GCC. The author also found that institutional and environmental barriers exist. The model goes on to list how to overcome these barriers.

A questionnaire was conducted on three groups in order to investigate attitudes and awareness of renewable energy amongst the general population (the public, academics, and government official spheres). According to the results, there have been recommendations listed.

Finally, a cost analysis was conducted to investigate whether renewable energy will economically and environmentally benefit Kuwait. Based on the results the author established a suggested future implementation road plan, that phases out traditional energy, replacing it with renewable energy. The model represents a comprehensive plan that will give decision makers a roadmap, highlighting the current situation and possible future of renewable energy, should the adoption of renewable energy be prioritized.

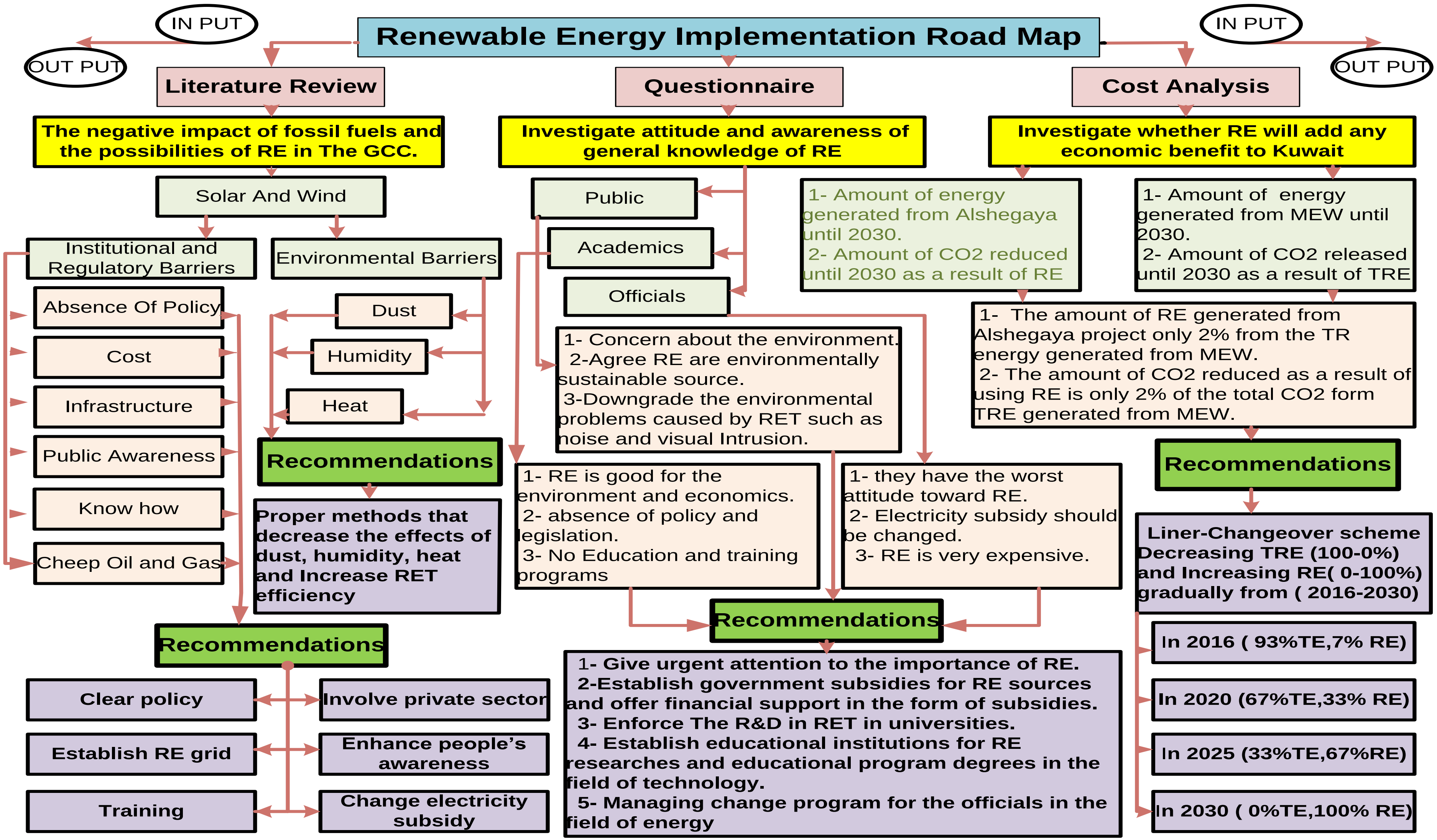

Figure 7.1: RE implementation road map

7.4 Suggestions for Future Work

Based on the outcome of this dissertation my suggestions for future work are as follows:

In order to obtain specific, clear, and more detailed information regarding the implementation of renewable energy in Kuwait, a qualitative method study should be undertaken with people who have not participated in this research questionnaire, including decision makers within the Kuwaiti government, and private business owners. A more intensive interview and approach with this specific target group would shed light on a clear vision of their attitude and knowledge regarding renewable energy.

A comprehensive mathematical model should be constructed. The model itself should contain all the elements related to RE implementations, including fossil fuels costs and availabilities, RET costs, RET efficiencies and the amount of pollution released. The constructed model will help provide numerical data to better visualize how the change in any of the elements will affect the outcome of RE and vice-versa.

Future economic forecasts should be carried out to determine the quantity of fossil fuels (oil and gas), measured in reserve years, will decrease in the absence of a RE project, and to determine how much of an increase in reserve years of those natural resources in the presence of RE projects will provide.

APPENDIXES

Appendix 1: RE Possibilities and Obstacles - Public, Officials and Academics

Dear Participant,

In this questionnaire, the term ‘renewable energy’ is defined as the energy that can be generated from ecological resources, which are naturally replenished. It will take no longer than 15 minutes to complete the questionnaire. This questionnaire is divided into three categories – Category 1: Demographic Information; Category 2: Background Information; Category 3: Attitude and knowledge.

The results of the questionnaire will provide information to the Kuwaiti government for better formation of policies and legislation on renewable energy as well as to understand the people and official attitudes and knowledge and barriers that might hinder the use of renewable energy for a better environment and more secure economy.

Thank you for your assistance,

Mohammad Alloughani

PhD candidate
Department of Electronic and Computer Engineering
Brunel University

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Direction: Please check (✓) the appropriate responses.

Part 1: Demographics

[1] Gender

☐ Female ☐ Male

[2] Age

☐ 20-25 ☐ 26-31 ☐ 32-37 ☐ 38-43 ☐ 44-49 ☐ 50-55 ☐ Over 56

[3] Highest degree earned

☐ Doctoral ☐Master ☐Bachelor ☐Diploma ☐High school ☐Below high school

Part 2: Background Information

[4] Do you think you are environmentally conscious?

☐ Yes ☐No

[5] Are you satisfied with the electricity price in Kuwait?

☐Yes ☐No

[7] Do you support the Kuwaiti government subsidizing electricity?

☐Yes ☐ No Why?...

[8] Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?

☐ Yes ☐No Why?...

[9] Would you support decreasing government electricity subsidy in order to promote renewable energy?

☐ Yes ☐No Why?...

[10] What are the benefits of using renewable energy sources to generate electricity? (check all that apply)

☐ Lower energy bills

☐ Good for the environment

☐ Less reliance on electric oil and natural gas

☐ There will not be a need for investment in nuclear power plants

☐ Good for the economy

☐ There is no benefit

Part 3: Questionnaire

- Scale 1: Attitude toward Renewable Energy

[11] I support the use of renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[12] All renewable energy sources are unattractive to me.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[13] There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[14] With the existing traditional fuels sources running out, the Kuwaiti government should not waste time investing in renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[15] I support the building of 'clean' renewable energy facilities to generate electricity in my local area.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[16] Individual households should support the cost of using renewable energy sources.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[17] I support the government's policy of generating our electricity needs from renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[18] Renewable energy technologies sites should not be located in my living area.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[19] Using renewable energy sources are ways of looking after our future in Kuwait.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

- Scale 2: Awareness of Own Knowledge of Renewable Energy and Its Barriers

[20] I am well informed about renewable energy sources (solar, wind, hydro-electric).

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[21] Reducing my household's energy consumption would help protect the environment.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[22] Renewable energy technology causes environmental damages and pollution.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[23] Renewable energy technologies have environmental problems such as noise and visual intrusion.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[24] In the future, we will no longer be able to use fossil fuels to generate electricity

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[25] Renewable energy sources are environmentally sustainable.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[26] Most of the air pollution in Kuwait is caused by production and use of oil and gas.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

OFFICIALS

Direction: Please check (✓) the appropriate responses.

Part 1: Demographics

[1] Gender:

☐ Female ☐ Male

[2] Age:

☐ 30-35 ☐ 36-41 ☐ 42-47 ☐ 48-53 ☐ Over 54

[3] Occupation:…………………………………………………………………………

Part 2: Background Information

[5] Do you think you are environmentally conscious?

☐ Yes ☐No

[6] Are you satisfied with the electricity price in Kuwait?

☐Yes ☐No

[7] Do you support the Kuwaiti government subsidizing electricity?

☐Yes ☐ No Why?...

[8] Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?

☐ Yes ☐No Why?...

[9] Would you support decreasing government electricity subsidy in order to promote renewable energy?

☐ Yes ☐No Why?...

[10] Do you intend to use form(s) of renewable energy in the future?

☐ Yes ☐No Why?...

If yes, what kind of renewable energy should you use? (check all that apply)

☐ Solar energy

☐ Wind energy

☐ Geothermal energy

☐ Hydroelectric energy

☐ Renewable biomass

[11] When did Kuwait start using this form of renewable energy?

☐ 1 year ago ☐ 2-5 years ago ☐ 6-9 years ago ☐ Over 10 years ☐ Never

[12] What is the main reason for using this form of renewable energy?

☐ Cost effectiveness

☐ Reliable & efficient

☐ Better quality power

☐ Environmental consideration

[13] How difficult is to start using renewable energy technologies to generate energy in Kuwait?

Very Difficult Very Easy

1 2 3 4 5 6

Please explain your answer……..…………………………………………………….

[14] What are the benefits of using renewable energy sources to generate electricity? (check all that apply)

☐ Lower energy bills

☐ Good for the environment

☐ Less reliance on electric oil and natural gas

☐ There will not be a need for investment in nuclear power plants

☐ Good for the economy

☐ There is no benefit

Part 3: Questionnaire

- Scale 1: Attitude toward Renewable Energy

[15] I support the use of renewable energy.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[16] Individual households should support the cost of using renewable energy.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[17] With the existing petroleum, the Kuwaiti government should not waste time investing in renewable energy technology.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[18] Renewable energy sources can play greater role in the world energy market.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[19] Kuwait should continue using the existing source of energy (petroleum) powered generators for electricity productions.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

- Scale 2: Awareness of Own Knowledge of Renewable Energy and Its Barriers

[20] Per person, Kuwaitis use more electricity than most other people in the world.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[21] Kuwaiti power generation and water desalination depends heavily on gas and oil.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[22] Renewable energy is more expensive than traditional fossil fuelled to generate electricity (such as coal, gas and oil).
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[23] Renewable energy technologies suffer the lack of skilled personnel and institutions research.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[24] The harsh environment in Kuwait is well-suited for solar and wind renewable sources.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[25] In the future, we will no longer be able to use fossil fuels to generate electricity

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[26] Renewable energy technologies very costly due to lack of competition.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[27] Renewable energy technology products suffer from lack of social acceptance.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[28] Solar energy source is considered a promising source of energy for Kuwait.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[29] The private sector should involve in the investment of renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[30] There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[31] There is a lack of reliable local data regarding the potential use and development of renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[32] There are more advantages than disadvantages in using renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

ACADEMICS

Direction: Please check (✓) the appropriate responses.

Part 1: Demographics

[1] Gender:

☐ Female ☐ Male

[2] Age:

☐ 30-35 ☐ 36-41 ☐ 42-47 ☐ 48-53 ☐ Over 54

[3] Degree earned

☐ Doctoral ☐Master

[4] Where did you study?

☐ Kuwait ☐ Abroad:

□ Europe □ North America □ Other, specify ………………………….

Part 2: Background Information

[5] Do you think you are environmentally conscious?

☐ Yes ☐No

[6] Are you satisfied with the electricity price in Kuwait?

☐Yes ☐No

[7] Do you support the Kuwaiti government subsidizing electricity?

☐Yes ☐ No Why?..

[8] Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?

☐ Yes ☐No Why?..

[9] Would you support decreasing government electricity subsidy in order to promote renewable energy?

☐ Yes ☐No Why?...

[10] What are the benefits of using renewable energy sources to generate electricity? (check all that apply)

☐ Lower energy bills

☐ Good for the environment

☐ Less reliance on electric oil and natural gas

☐ There will not be a need for investment in nuclear power plants

☐ Good for the economy

☐ There is no benefit

[11] Do you think Kuwait is ready to switch to form(s) of renewable energy in the future?

☐ Yes ☐No Why?...

If yes, what kind of renewable energy should you use? (check all that apply)

☐ Solar energy

☐ Wind energy

☐ Geothermal energy

☐ Hydroelectric energy

☐ Renewable biomass

☐ Other

[12] How difficult is to start using renewable energy technologies to generate energy in Kuwait?

Very Difficult Very Easy

1 2 3 4 5 6

Please explain your answer……..……………………………………………………

Part 3: Questionnaire

- Scale 1: Attitude toward Renewable Energy

[13] I support the use of renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[14] I support the building of ‘clean’ renewable energy facilities to generate electricity in my local area.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[15] The Kuwaiti government should support pilot demonstration projects for every type of renewable energy technology.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[16] There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[17] The Kuwaiti government should ensure the study of renewable energy technologies in its education system (colleges and research centres).

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[18] Using renewable energy sources is a way of looking after our future.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[19] Renewable energy sources can play greater role in the world energy market.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[20] Individual households should support the cost of using renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

- Scale 2: Awareness of Own Knowledge of Renewable Energy and Its Barriers

[21] Renewable energy sources are environmentally sustainable energy supplies.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[22] Most of the air pollution in Kuwait is caused by production and use of oil and gas.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[23] Renewable Energy Technology productions are very costly.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[24] Renewable energy technologies have technical barrier due to the lack of skilled personnel, policy and institutions.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[25] Private sector should works with the government to create stabile long-term investment in the renewable energy.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[26] In the future, we will no longer be able to use fossil fuels to generate electricity
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[27] Kuwait needs new environmental laws and regulations.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[28] There is a lack of renewable energy educational programs and degrees in Kuwait’s higher education system.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[29] Renewable energy technologies have environmental problems such as noise and visual intrusion.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[30] The harsh environment in Kuwait is well-suited for solar and wind renewable energies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[31] Renewable energy technologies are more expensive than traditional fossil fuelled electricity supplies (such as coal, gas and oil).

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[32] Renewable energy market failed due to government monopoly of energy supply

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[33] Renewable energy technologies suffer from the lack of awareness.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[34] The Kuwaiti government needs to establish link between regional renewable energy research and local centres.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[35] There is a lack of renewable energy educational programs and degrees in Kuwait's higher education system.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[36] Solar is considered a promising source of energy for Kuwait.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[37] Renewable energy technology products suffer from lack of social acceptance.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[38] There are more advantages than disadvantages in using renewable energy technologies

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[39] Renewable energy technologies suffer from the uncertain government policies and legislations.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[40] Renewable energies can create significant new employment opportunities in energy infrastructure manufacturing, installation, and maintenance.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[41] Renewable energy technologies faces poor market due to lack of competition.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

Direction: Please check (✓) the appropriate responses.

Part 1: Demographics

[1] Gender:

☐ Female ☐ Male

[2] Age:

☐ 30-35 ☐ 36-41 ☐ 42-47 ☐ 48-53 ☐ Over 54

[3] Years of experience

………………………………………………………………………………………

[4] Employment

…………………………………………………………………….…………………

[5] Occupation

☐ Employee ☐ Assistant manager ☐ Manager ☐ Top manager

☐ Academic ☐ Retired ☐ Technical

Other…………………………………………………………………………………

[6] Highest degree earned

☐ Doctoral ☐ Master ☐ Bachelor ☐ Diploma ☐ High school ☐ Less than high school

[7] Where did you study?

………………………………………………………………………………………

…….…………………………………..……………………………………………

[8] Please indicate the courses you took in school concerning renewable energy

……………………………………………………………………………………………

………..………………………………………………………………………………

[9] Please list workshops or/and conferences on renewable energy you attended doing your employment

………..…………………..……………………………………………………………

……………………………………………………………………………..……………

Part 2: Background Information

[10] Do you think you are environmentally conscious?

☐ Yes ☐No

[11] Are you aware of the importance of electricity consumption in Kuwait?

☐Yes ☐No

How?..

[12] Are you satisfied with the electricity price in Kuwait?

☐Yes ☐No

[13] Have you seen or heard anything about renewable energy recently?

☐ Yes ☐No if yes where did you hear about it?

…………..………………………………………………………………

[14] Are you familiar with renewable energy technology and their benefits?

☐ Yes ☐ No

[15] What kind of renewable energy are you familiar with?

☐ Hydroelectric energy ☐ Solar energy ☐ Wind energy ☐ Geothermal energy

[16] Do you support the Kuwaiti government subsidizing electricity?

☐Yes ☐ No Why?...

[17] Should the Kuwaiti government be more active in providing information on ways to reduce energy consumption?

☐ Yes ☐No Why?...

[18] Should the Kuwaiti government create an energy efficiency grant scheme to help the people in Kuwait to become energy efficiency?

☐ Yes ☐No Why?...

[19] Would you support a decrease in government electricity subsidy in order to promote renewable energy?

☐ Yes ☐No Why?...

[20] What do you think of the use of renewable energy?

…………………………………………………………………………………………

…………………………………………………………………………………………

[21] Do you think that the use of renewable energy sources will affect the global climate positively?

…………………………………………………………………………………………

…………………………………………………………………………………………

[22] Would you say that it is better to use renewable energy sources for creating electricity or to use the traditional sources which involve burning fossil fuels?

…………………………………………………………………………………………

…………………………………………………………………………………………

[23] Does the Kuwaiti government use any form of renewable energy?

☐ Yes ☐No

If yes, what kind of renewable energy? (check all that apply)

☐ Solar energy
☐ Wind energy
☐ Geothermal energy
☐ Hydroelectric energy
☐ Hydrokinetic energy
☐ Ocean energy
☐ Renewable biomass
☐ Other……………………………………………………

[24] When did Kuwait start using this form of renewable energy?
☐ 1 year ago ☐ 2-5 years ago ☐ 6-9 years ago ☐ Over 10 years ☐ Never

[25] What is the main reason for using this form of renewable energy?
☐ Cost effectiveness
☐ Reliable & efficient
☐ Better quality power
☐ Environmental consideration

[26] What is the use of this form of renewable energy?
……………………………………………………………………………………………
……………………………………………………………………………………………

[27] How much do you estimate the government will save by using this form of energy?
……………………………………………………………………………………………
……………………………………………………………………………………………

[28] Do you intend to switch to form(s) of renewable energy in the future?
☐ Yes ☐No Why?...

If yes, what kind of renewable energy should you use? (check all that apply)

☐ Solar energy
☐ Wind energy
☐ Geothermal energy
☐ Hydroelectric energy
☐ Renewable biomass
☐Other

[29] How difficult is to start using renewable energy technologies to generate energy in Kuwait?

Very Difficult Very Easy

1 2 3 4 5 6

Please explain your answer……..……………………………………………………

[30] What are the benefits of using renewable energy sources to generate electricity? (check all that apply)

☐ Lower energy bills
☐ Good for the environment
☐ Less reliance on electric oil and natural gas
☐ There will not be a need for investment in nuclear power plants
☐ Good for the economy
☐ There is no benefit

[31] Which of the following renewable energy sources would you consider for home electricity?

☐ Thermal instruction of the houses

☐ Solar hot water heating

☐ Solar space heating

☐ Attached greenhouse

☐ Solar pool heating

☐ Photovoltaic electricity generation

☐ Geothermal hot water/space heating

☐ Use of solid fuel with biomass content

[32] To satisfy the future energy needs of Kuwait, which options should be prioritized (check all that apply)?

☐ Nuclear power plants

☐ Power plants that rely on renewable energy resources such as hydro or wind

☐ Natural gas power plants

☐ Coal fired power plants

☐ Solar and/or wind

[33] What is your opinion of renewable energy?

☐ Very good idea

☐ Fairly good idea

☐ Neither a good idea nor a bad idea

☐ Fairly bad idea

☐ Very bad idea

☐ I don’t know

Why? ……………………………………………………………….........

Part 3: Questionnaire

- Scale 1: Attitude toward Renewable Energy

[34] There is an urgent need to reduce environmental pollution and cut greenhouse gas emissions to the atmosphere.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[35] Kuwait should continue using the current powered generators for electricity productions.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[36] The Kuwaiti government should encourage the use of renewable energy resources.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[37] I support the use of renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[38] Kuwaiti government should promote energy conservation/efficiency rather than investing in renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[39] Renewable energy sites technologies should not be located in my living area.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[40] All renewable energy sources are unattractive to me.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[41] Using renewable energy sources is a way of looking after our future.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[42] Individual households should support the cost of using renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[43] I support the building of ‘clean’ renewable energy facilities to generate electricity in my local area.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[44] I support the government’s policy of generating part of our electricity needs from renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[45] The Kuwaiti government should support pilot demonstration projects for every type of renewable energy technology.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[46] The Kuwaiti government should ensure the study of renewable energy technologies in its education system, including in colleges.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[47] With the existing petroleum, the Kuwaiti government should not waste time investing in renewable energy technology.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[48] The Kuwaiti government should give urgent attention to the renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[49] Renewable energy sources can play greater role in the world energy market.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[50] Renewable energy sources are equally important as fossil fuels.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

- Scale 2: Awareness of Own Knowledge of Renewable Energy: Its Use, Benefits & Barriers

[51] Renewable energy market failed due to government monopoly of energy supply

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[52] Kuwait economics depends heavily on gas and oil productions.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[53] Renewable Energy Technology production is very costly due to high cost of product and resources such as materials, labour, capital, implementation and high cost user.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[54] Renewable energy technologies faces poor market infrastructure due to lack of competition.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[55] Renewable energy technologies suffer from the lack of awareness.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[56] Renewable energy technologies suffer from lack of knowledge of technology access and use.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[57] Renewable energy has a technical barrier due to the lack of skilled personnel and institutions.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[58] Renewable energy technology products suffer from lack of consumer and social acceptance.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[59] Renewable energy technologies suffer from the uncertain government policies and legislations.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[60] Renewable energy technology causes environmental damages and pollution.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[61] There is a lack of reliable local data regarding the potential use and development of renewable energy technologies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[62] Kuwait has the potential for exploiting renewable energy sources, especially solar energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[63] Kuwait lacks a policy framework and planning constraints for renewable energies and energy efficiency.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[64] Kuwaiti power generation and water desalination depends heavily on gas and oil.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[65] Wind is considered a promising source of energy for Kuwait.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[66] The Kuwaiti government needs to establish link between regional renewable energy research and local centres.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[67] There is a lack of renewable energy educational programs and degrees in Kuwait’s higher education system.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[68] The private sector should involve the Kuwaiti government stakeholders to create stabile long-term investment in the renewable energy.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[69] The harsh environment in Kuwait is well-suited for solar and wind renewable energies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[70] There is a rapid growth of the renewable energy industry worldwide.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[71] The various renewable energy technologies are not cost effective.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[72] Renewable energies help reduce the pollution intensity of economic activities.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[73] Substituting renewables for some of the fossil fuels used in the heat and transport fuel markets would reduce the level of harmful emissions to the atmosphere.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[74] Renewable energies are environmentally sustainable energy supplies.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[75] Renewable energies can create significant new employment opportunities in energy infrastructure manufacturing, installation, and maintenance.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[76] Renewable energies have environmental problems such as noise and visual intrusion.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[77] Kuwait needs no new environmental laws and regulations.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[78] The Earth has plenty of natural resources if we learn how to develop them.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[79] Most of the air pollution in Kuwait is caused by production and use of oil and gas.

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[80] About half of Kuwait's CO_2 emissions come from electricity generation.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[81] Per person, Kuwaitis use more electricity than most other people in the world.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[82] Generating electricity from renewable energy sources (solar, hydro-electric, wind, biomass) costs about the same as generating electricity from fuels.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[83] There is strong debate in the scientific community about whether climate change is a real problem.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[84] I am well informed about climate change.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[85] Reducing my household's energy consumption would help protect the environment.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[86] I am well informed about renewable energy sources (solar, wind, hydro-electric).
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[87] The government urges me to reduce my household energy consumption.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[88] Renewable energy is more expensive than traditional fossil fuelled electricity supplies (such as coal, gas and oil).
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[89] There are more advantages than disadvantages to using renewable energy.
☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

[90] In the future, we will no longer be able to use fossil fuels to generate electricity

☐ Strongly Agree ☐ Agree ☐ Undecided ☐ Disagree ☐Strongly disagree

Appendix 2: Finding best fit formula for energy consumption for the period 1992-2020

The following graphs shows how various polynomial fittings to the data of electricity generated in Kuwait for the period 1992 to 2020 as published in a MEW document.

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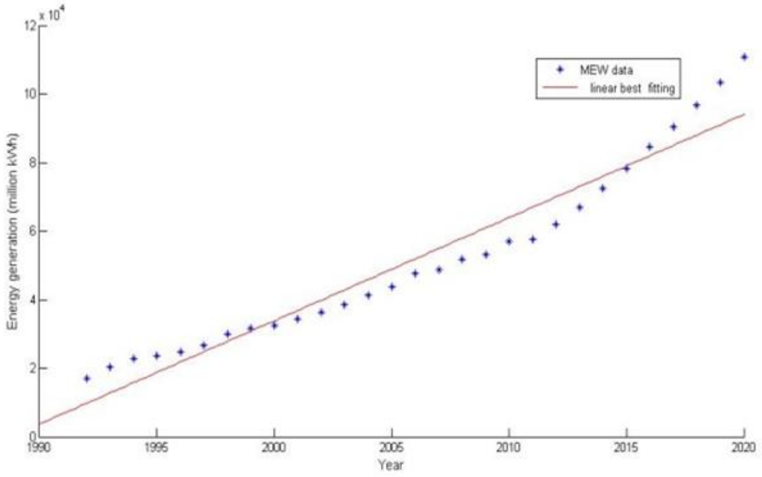
<td>


</td>
<td>(1)
Linear</td>
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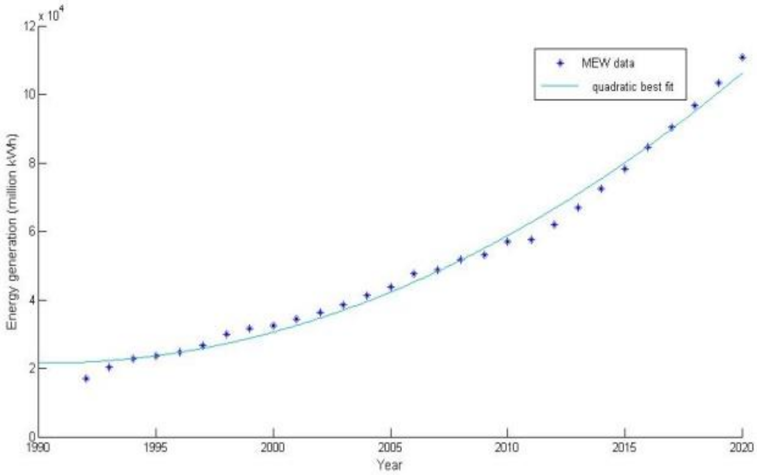

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<td>(2)
Second order</td>
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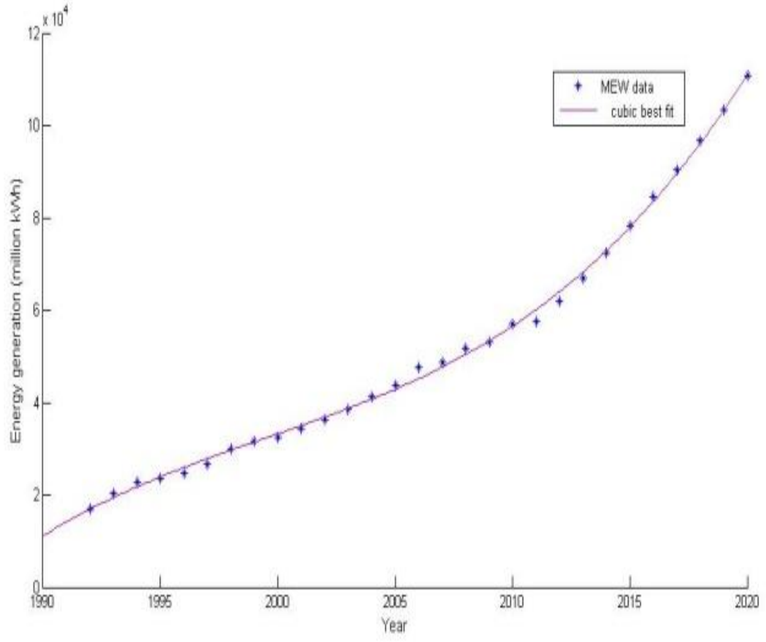
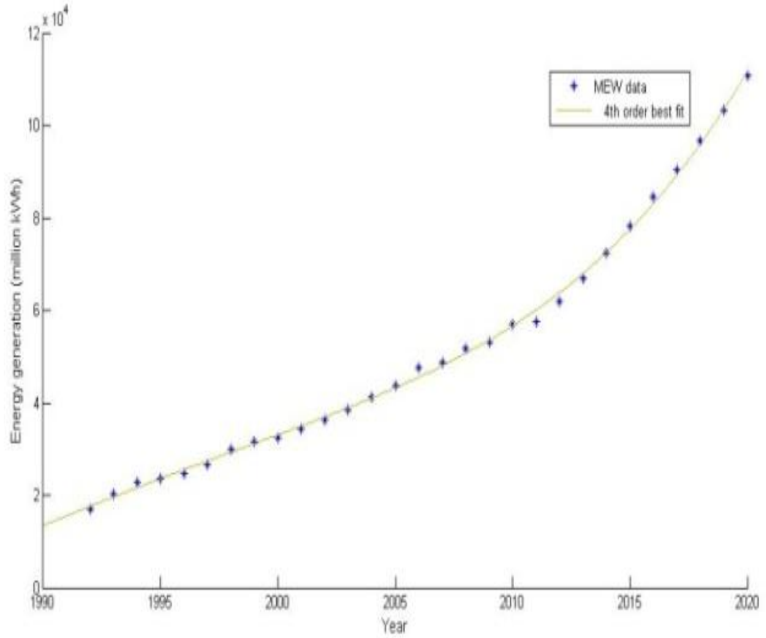
	(3) Third order
	(4) Fourth order

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