Smart-Streetscape Elements as a Sustainable Approach for Generating Renewable Energy and Reducing the Roads Carbon Emissions in Egyptian Cities

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ABSTRACT

The energy supply, especially the electricity supply become more recently the backbone of all modern industrial, information and service societies, the global energy consumption has doubled in the last three decades of the past century. The world started since then to take actions facing the shortage of non-renewable fuel resources and investigating solutions relying on renewable resources. Researches were conducted to solve the shortage of non-renewable fuel resources and replaced it with renewable resources as a way for creating sustainable neighbourhood. Creating sustainable neighbourhood was the concern of researchers in the past few years with many studies addressing their social, economic and environmental parameters.

The main concern of this research is that the neighbourhoods in the developing countries such as Egypt produce a high level of carbon emissions. The level of carbon emissions in these countries is increasing with very high rates due to the heavy use of fossil fuels. Countries with a high use of renewable energy have a lower carbon energy mix, while countries with a high use of coal have much higher carbon intensity than the global average. In addition to that, these countries are facing a shortage in their basic needs for power supply due to urban and economic expansion. The governments of the developing countries can't provide the power demand to the community and that conducts a lack of electricity in many neighbourhoods and districts. Relying on non-renewable sources is not a solution for these countries.

Reducing road carbon emissions and creating sustainable neighbourhoods is the scope of this research. Reduction of carbon emission will be examined in this research using "Smart-Streetscape elements (SSSE)" which are, as defined in this research, an innovative method that integrates renewable energy (RE) devices with streetscape elements. Smart-Streetscape elements will reduce the carbon emissions produced in roads using short term and long term strategies. Reducing Co_2 emissions in the short term will be achieved by controlling the energy reduction and energy generation using RE devices to generate clean and effect energy suitable for generating electricity for street lighting and public facilities. Reducing Co_2 emissions in the long term is achievable by creating the infrastructure needed for electric vehicles to operate efficiently and by providing an infrastructure and power supply for electric spencer's which is used to charge the electric vehicles. This will encourage residents to use electric vehicles instead of fuel vehicles, especially that fuel prices are higher than electricity prices.

Creating sustainable neighbourhood using Smart-Streetscape elements (SSSE) will help in reducing energy taken from government and will affect neighbourhood economic state as well as it will help in reducing the growth of global problems such as carbon emissions, ozone depletion, and climate change.

A new software will be presented in this research as well. This software is called “SSSE” and it will be used to locate the most suitable places for using Smart-Streetscape elements. It will calculate the amount of energy produced from each Smart-Streetscape element, the cost of each element, the area needed to operate each element, and finally it will present the life time and annual maintenance cost of each element. Moreover, it will provide the user with a bubble diagram identifying the best location for the chosen Smart-Streetscape element. This software will be used in this research case study and the results will help this research to choose the type and location of Smart-Streetscape element in order to reach the main goal of this research which is creating sustainable neighbourhood with low carbon emissions using Smart-Streetscape element.

The expected outcome is a new carbon emission model which can estimate the amount of carbon emission produced from a road in the design phase as well as it can measure the amount of real-time carbon emissions produced from existing road. Moreover, this research will identify new sustainable elements called Smart-Streetscape elements (SSSE) and it will present its properties. In addition to that, this research will apply Smart-Streetscape elements (SSSE) in existing street in Egypt and a new design for its streetscape will be presented using Smart-Streetscape elements (SSSE) that can be considered sustainable design and energy efficiently. The efficiency of Smart-Streetscape elements toward energy generation and carbon reduction will be measured in this case study.

ABSTRAKT

Die Energieversorgung, insbesondere die Stromversorgung, ist vor kurzem zum Rückgrat aller modernen Industrie-, Informations- und Dienstleistungsgesellschaften geworden, der weltweite Energieverbrauch hat sich in den letzten drei Jahrzehnten des vergangenen Jahrhunderts verdoppelt. Seitdem hat die Welt begonnen, Maßnahmen zu ergreifen, um der Verknappung nicht erneuerbarer Brennstoffressourcen zu begegnen und Lösungen zu suchen, die auf erneuerbaren Ressourcen beruhen. Es wurden Untersuchungen durchgeführt, um den Mangel an nicht erneuerbaren Brennstoffressourcen zu beheben und diese durch erneuerbare Ressourcen zu ersetzen, um eine nachhaltige Nachbarschaft zu schaffen.
Die Schaffung einer nachhaltigen Nachbarschaft war in den letzten Jahren das Anliegen von Forschern mit vielen Studien, die sich mit ihren sozialen, wirtschaftlichen und ökologischen Parametern befassten.

Das Hauptanliegen dieser Forschung ist, dass die Nachbarschaften in den Entwicklungsländern, wie Ägypten, hohe CO2-Emissionen produzieren. Die CO_2-Emissionen in diesen Ländern steigen aufgrund des starken Verbrauchs fossiler Brennstoffe mit sehr hohen Raten. Länder mit einem hohen Einsatz erneuerbarer Energien haben einen geringeren CO_2-Energiemix, während Länder mit einem hohen Kohleverbrauch eine viel höhere CO_2-Intensität als der globale Durchschnitt aufweisen. Darüber hinaus sind diese Länder aufgrund der städtischen und wirtschaftlichen Expansion mit einer Verknappung ihres Die Regierungen der Entwicklungsländer können den Strombedarf ihrer Gemeinden nicht decken, daher fehlt es in vielen Stadtteilen und Bezirken an Strom. Sich auf nicht erneuerbare Quellen zu verlassen, ist keine Lösung.. Reducing the roads carbon emissions and creating sustainable neighbourhoods is the scope of this research. The reduction of the roads carbon emission will be presented in this research using new elements reffered to this research as “Smart-Streetscape elements (SSSE)”.

Die Reduzierung der CO2-Emissionen im Straßenverkehr und die Schaffung nachhaltiger Nachbarschaften ist das Ziel dieser Forschung. Die Reduzierung des CO2-Ausstoßes wird in dieser Forschung anhand von „Smart-Streetscape-Elementen (SSSE)“ untersucht, die, wie in dieser Forschung definiert, eine innovative Methode sind, die Geräte mit erneuerbaren Energien (RE) in Straßenlandschaftselemente integriert. Smart-Streetscape-Elemente werden mit kurz- und langfristigen Strategien die CO2-Emissionen von Straßen reduzieren. Die kurzfristige Reduzierung der Co2-Emissionen wird durch die Steuerung der Energieeinsparung und Energieerzeugung mit EE-

Geräten erreicht, um saubere und effektive Energie zu erzeugen, die zur Stromerzeugung für Straßenbeleuchtung und öffentliche Einrichtungen geeignet ist. Eine langfristige Reduzierung des Co2-Ausstoßes ist erreichbar, indem die für den effizienten Betrieb von Elektrofahrzeugen erforderliche Infrastruktur geschaffen wird und eine Infrastruktur und Stromversorgung für Elektroautos bereitgestellt wird, die zum Laden der Elektrofahrzeuge verwendet werden. Dies wird die Einwohner dazu ermutigen, Elektrofahrzeuge anstelle von Kraftstofffahrzeugen zu verwenden, insbesondere da die Kraftstoffpreise höher sind als die Strompreise.

Die Schaffung einer nachhaltigen Nachbarschaft mit Smart-Streetscape-Elementen (SSSE) wird dazu beitragen, die von der Regierung abgezogene Energie zu reduzieren und den Wirtschaftszustand der Nachbarschaft zu beeinflussen sowie das Wachstum globaler Probleme wie Kohlenstoffemissionen, Ozonabbau und Klimawandel zu reduzieren.

Auch bei dieser Untersuchung wird eine neue Software eingeführt. Diese Software heißt „SSSE“ und wird verwendet, um Orte zu finden, die am besten für die Verwendung von Smart-Streetscape-Elementen geeignet sind. Es berechnet die von jedem Smart-Streetscape-Element erzeugte Energiemenge, die Kosten jedes Elements, die für den Betrieb jedes Elements benötigte Fläche und zeigt letztendlich die Lebensdauer und die jährlichen Wartungskosten jedes Elements an. Darüber hinaus bietet es dem Benutzer ein Blasendiagramm, das den besten Standort für das ausgewählte Smart-Streetscape-Element identifiziert. Diese Software wird im Studienfall dieser Forschung verwendet, und die Ergebnisse werden helfen, den Typ und die Position des Smart-Streetscape-Elements auszuwählen, um das Hauptziel dieser Forschung zu erreichen, nämlich eine nachhaltige Nachbarschaft mit geringen CO2-Emissionen mit dem Smart-Streetscape-Element zu schaffen .

Das erwartete Ergebnis ist ein neues CO2-Emissionsmodell, das die Menge der CO2-Emissionen, die auf einer Straße in der Entwurfsphase erzeugt werden, abschätzen und die Menge der CO2-Emissionen, die auf bestehenden Straßen in Echtzeit erzeugt werden, messen können. Darüber hinaus präsentiert diese Forschung innovative nachhaltige Elemente, die als Smart-Streetscape-Elemente (SSSE) bezeichnet werden, zusammen mit ihren Eigenschaften. Darüber hinaus wendet es Smart-Streetscape-Elemente (SSSE) auf bestehende Straßen in Ägypten an, und es wird ein neues, für sein Straßenbild geeignetes Design mit Smart-Streetscape-Elementen (SSSE) präsentiert, die als nachhaltig gestaltet und energieeffizient gelten können. In dieser Fallstudie wird die Effizienz von Smart-Streetscape-Elementen hinsichtlich Energieerzeugung und CO2-Reduzierung gemessen.

TABLE OF CONTENTS

CHAPTER THREE: RENEWABLE ENERGY AND STREETSCAPE FRAMEWORKS

CHAPTER FOUR: EMPIRICAL SECTION

CHAPTER FIVE: RESEARCH APPLICATION, DISCUSSION AND CONCLUSION

REFERENCES

List of Tables

List of Figures

CHAPTER ONE

INTRODUCTION

1.1. BACKGROUND INFORMATION

Energy conservation is one of the strategies that evolved since the 1970's; it firstly began due to the energy crisis at that time, the world started since then to take actions facing the shortage of non-renewable fuel resources and investigating solutions relaying on renewable resources. The importance of energy conservation increased and became essential in the late 1980's, and its role has been grown since then due to the growth of global problems such as ozone depletion and climate change (IEA, 2004). Today, Energy is a key element for urban development, it is the essential for all human activities such as industry, agriculture, housing, services, and transportation.

The energy-policy in the MENA region continues to be considered independent of non-renewable, fossil energy sources. Egypt, as many other countries, depend heavily on traditional energy sources as crude oil, natural gas, and hydroelectric energy. According to Egyptian-German Private Sector Development Program, the energy situation in Egypt is dangerous due to the current or expected decline of domestic oil and natural gas resources (Sawin & Mastny, 2010).

Egyptian petroleum and other liquids production is decreasing and the demand of consumption is increasing as shown in figure [1-1], that means that depending on fossil fuel should not be the main option in Egypt.

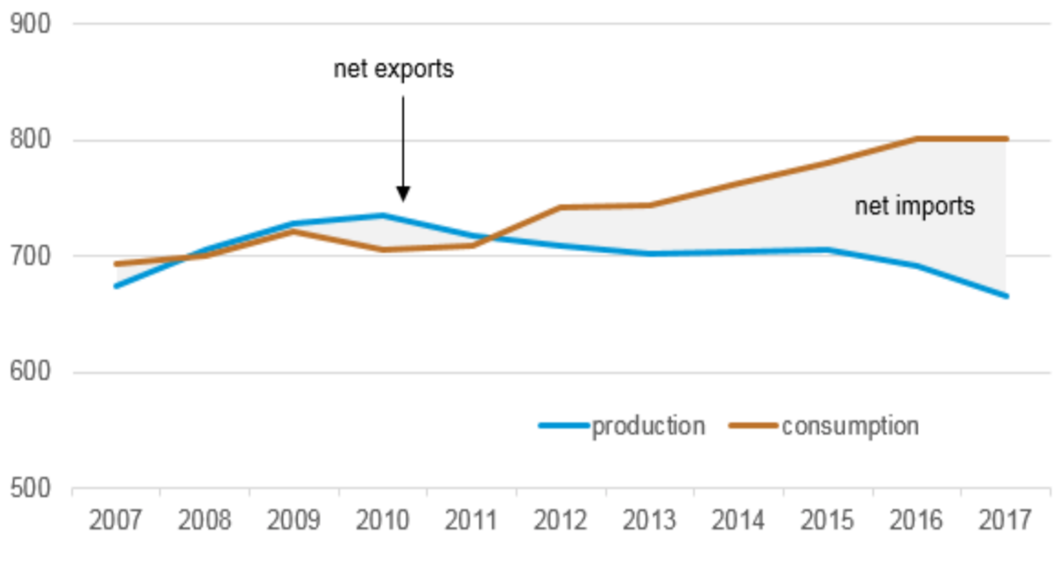


Figure [1-1]: Annual Petroleum and other liquids production and consumption in Egypt
Source: (EIA, 2018)

The Egyptian oil production declined for more than a decade after reaching a peak in the mid-1990s of more than 900,000 b/d]. About half of Egypt's oil production comes from the Western Desert and the remainder comes from Sinai, Gulf of Suez, Mediterranean Sea, Eastern Desert, Upper Egypt and

Nile Delta. Most of Egypt's production is derived from relatively small fields that are connected to larger regional production systems (EIA, 2018)

As shown in figure [1-1].

In 2008, increased output from the Western Desert and offshore areas helped to increase production over the next few years, but production started to decline again shortly after that. The use of enhanced oil recovery (EOR) techniques at mature fields has eased production declines. One of Egypt's main challenges is to satisfy increasing domestic oil demand. Total oil consumption grew by an annual average of 3% throughout the past 10 years, with around 775,000 b/d in 2014. Nowadays, Egypt's oil consumption exceeds production (Abu-Jeries, Elkhayat, Mahmoud, & Al-Salaymeh, 2016, p. 17).

Natural gas is one of the most important source of energy in Egypt. The production of natural gas is more than the consumption level but the public demand is increasing and shortly the production will be equal to the consumption. Egypt produces 2300 billion cubic feet of gas every year which equal 383 million barrel of oil/year, while the annual gas consumption is about 242 million barrel/year as shown in figure [1-2]. Figure [1-2] shows the growth in gas productivity, also shows the growth in the demand, taking into consideration the deterioration in oil productivity and the growth in the demand.

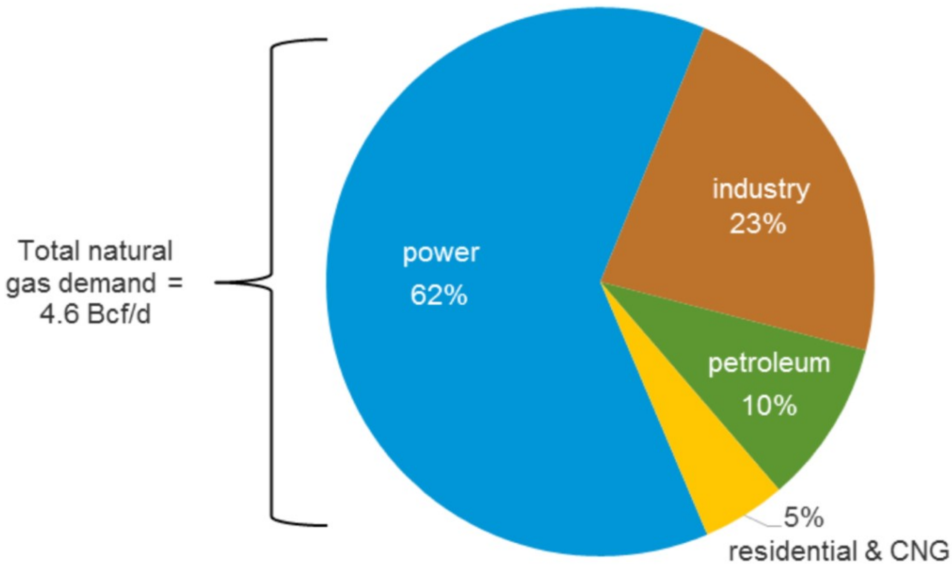


Figure [1-2]: Natural Gas Demand by Sector
Source: (BP , 2017)

The Electricity demand in Egypt has grown significantly in the last years due to the country social and economic development. The Egyptian electricity consumption has increased from 49 TWh to 111 TWh between 1996; 1997 and 2008; 2009 with a current growth rate more than 7% per year, and it increased by more than 200% between 1990 and in 2009 (Attia and Wanas, 2012, pp.1-8).

In 2018, CO_2 emissions for Egypt was 250,660 kt. The emissions increased from 122,411.6 kt in 1999 to 250,660 kt in 2018 growing at an average annual rate of 4.02% (KNOEMA, 2018). CO_2 emissions from the transport sector alone represent about a quarter of global CO_2 emissions from fossil fuels. As with current trends of the transportation sector worldwide, there is consensus among supporters of sustainability that a paradigm shift toward low-carbon mobility is needed, requiring investment in public transportation, and reduction of private vehicle use among other travel demand measures, as well as encouraging use of more efficient vehicle technologies (Wang & Ge, 2019).

Recently, in Egypt new sources of energy, (non- traditional) energy has been introduced and used such as wind and solar energy. The geographical location of Egypt is of great potential and specially, potential of using solar energy.

The Sustainable Development Strategy: Egypt Vision 2030 was announced in February 2016 and it reveals the country's aspirations to reach a competitive, balanced and diversified economy by 2030 to secure sustainable development in a good environment for all Egyptians. The strategy identified a set of development indicators to be reached by 2020 and 2030. Among those indicators, some are related to renewable energy as shown in table 1 (IRENA, 2018, p. 3).

Table [1-1] Development indicators of Egypt's Vision 2030
Source: (IRENA, 2018)

Targeted development indicators	2016*	2020	2030
GDP real growth (%)	4.2	10.0	12.0
GDP per capita (USD)	3 436	4 000	10 000
Inflation rate (CPI, annual %)	11.8	8.0	5.3
Industrial development rate (%)	5.0	8.0	10.0
Industry share of GDP (%)	12.5	15.0	18.0
Energy sector share of GDP (%)	13.1	20.0	25.0
Renewables' share in primary energy (%)	1.0	8.0	12.0
Renewables in electricity production (%)	1.0	21.0	32.5
Women in workforce (%)	22.8	25.0	35.0
Unemployment rate (%)	12.8	10.0	5.0
Poverty rate (%)	26.3	23.0	15.0
Acute poverty (%)	4.4	2.5	0.0

Several renewable energy projects are now taking place, in attempt to turn the vision into reality. Several projects nowadays have attracted strong international interest and promising proposals, which could further help increase renewable power generation in the coming years. The government's latest targets call for 20% of Egypt's power generation to be based on renewables by 2022, and 42% by 2035 (IRENA, 2018, p. II).

Solar energy and Photo cells: This type of energy is available easily with a highly significant quantity relative to other countries, this non-traditional resource is available all over the deserts, specially, west desert area, photovoltaic cells is a common way to generate energy in deferent countries all over the word but it is still not wildly used in Egypt due to its highly initial cost.

Wind energy: wind energy is one of the most important sources of energy all over the world figure [1-3] show the growth in the total installed wind capacity from 2002 till 2013. Egypt produce an average of 1100MW from wild turbines. The (Elsobki, Wooders, & Sherif , 2009, pp. 17, 18).

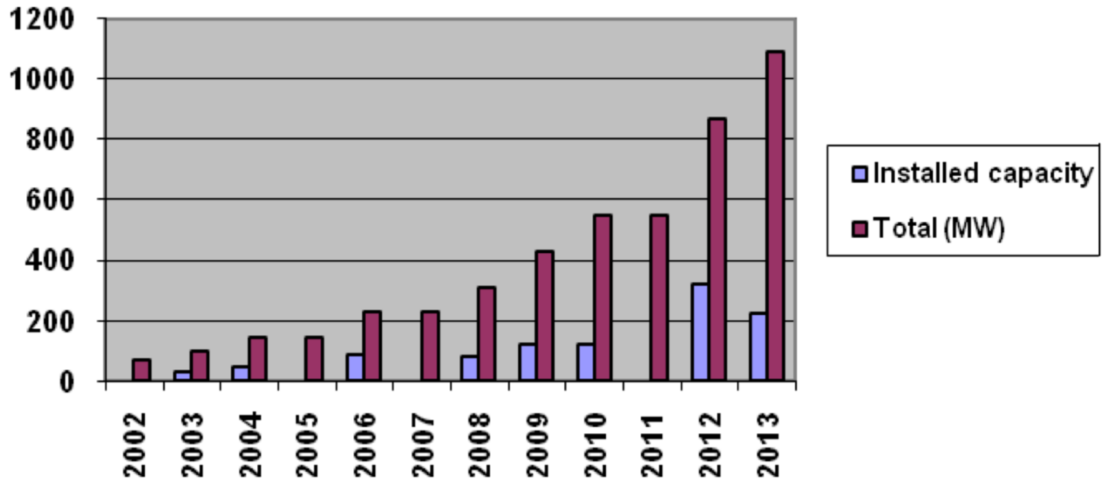


Figure [1-3]: NREA wind farms total installed capacity in Egypt
Source: (Elsobki, Wooders, & Sherif , 2009)

In April 2007, the Supreme Council of Energy announced a new strategy aiming to increase the share of wind energy such that it would represent 12% of total electricity demand in the 2020–2021. Figure [1-4] illustrates the increase in installed capacity as well as the MW which raises to almost 9000 MW.

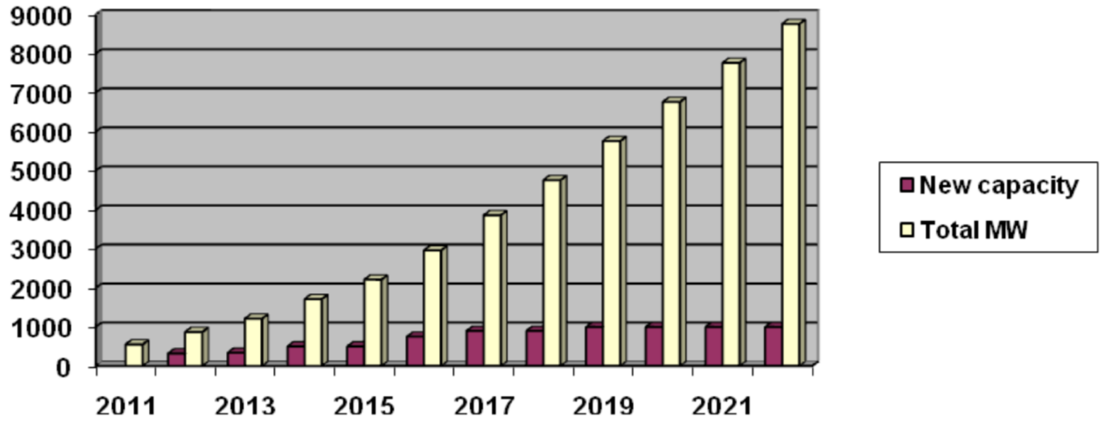


Figure [1-4]: Proposed time schedule for additional wind farm capacities
Source: (Elsobki, Wooders, & Sherif , 2009)

Egypt has the potential of land, sunny weather and high wind speeds, making it an excellent location for renewable energy sources. Egypt intends to increase the supply of electricity generated from renewable sources to 20% by 2022 and 42% by 2035, with wind providing 14%, hydro power 2%, and solar 25% by 2035 (Bissada, 2019).

The national projects for generating energy from renewable resources is shown in figure [1-5]. The map illustrate the new zones of projects that will electrified Egypt by 2020 using wind and solar energy. Wind energy will be concentrated in the Suez golf spin, north coast, west, east Manya. While solar energy will be concentrated in Kom Ambo south Egypt (NREA, 2018, p. 23).

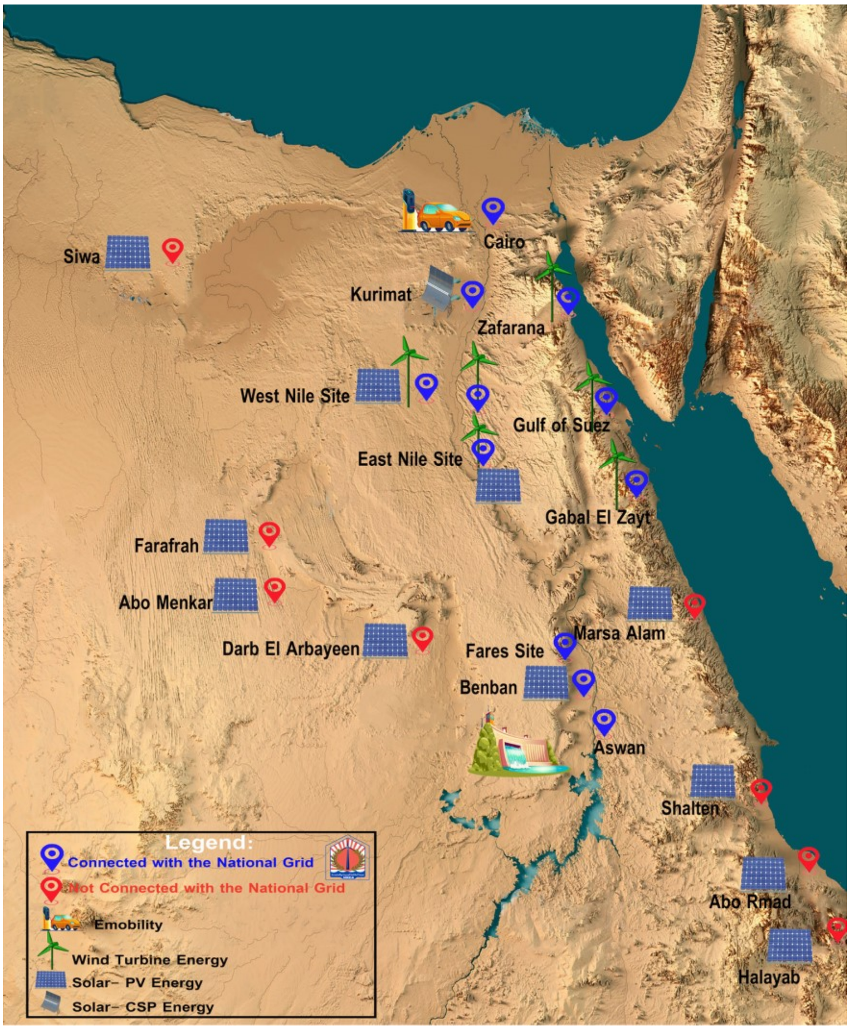


Figure [1-5]: National projects for generating energy in Egypt
Source: (NREA, 2018)

This research focus on reducing the streets carbon emissions in Egyptian cities by creating and introducing new sustainable elements called "Smart-Streetscape elements (SSSE)" and replace the regular streetscape elements with this sustainable elements. Smart-Streetscape elements (SSSE) is an outcome for the integration of renewable energy with streetscape elements. This research called the integration between renewable energy with streetscape elements "Smart-streetscape elements".

This research intend to use the term "Smart-streetscape elements" to identify the integration between renewable energy with streetscape elements because this integration will generated clean energy from streetscape elements using renewable energy devices without compensating the properties and function of streetscape elements, in which it will termed the regular streetscape elements into sustainable and smart elements.

1.2. RESEARCH PROBLEM

According to previous researches, almost a quarter of the global CO_2 emissions are produced from roads and transport sector. Increasing the level of CO_2 emissions threat the balance of the ecosystem, human lives, public health and the existence of flora and fauna.

The problem of this research is that the rate of CO_2 emissions in developing countries such as Egypt is increasing specially from the roads and transportation sector, relaying on electric cars to reduce the roads carbon emissions in this countries is not a solution due to the lack of infrastructure and power supply needed. Moreover, the neighbourhoods and cities in these countries are facing a shortage in their basic needs for power supply due to urban and economic expansion while the energy production is still limited, the governments cannot provide the energy demand to the neighbourhoods and cities and that conducts a lack of electricity in many neighbourhoods in these countries, so replaying on the governments to provide electricity for electric spencer to generate electric cars in not an option.

Many researches discussed the environmental potentials of streetscape elements in reducing the energy used although streetscapes elements have a great potential to generate energy because it is wildly spreads all over the neighbourhoods. But almost no researcher discussed this potential.

This research intends to study the effect of integrating streetscape elements and renewable energy devices in creating Smart-Streetscape elements (SSSE) as a tool of generating clean energy that used for short term strategy in lighting the streets and the neighbourhood's public facilities. While, for the long term strategy, it provide an instruction for electric spencer that is used to charge the electric vehicles as a long term solution to reduce the roads carbon emissions.

1.3. OBJECTIVES

The main goal of this research is to reducing the Egyptian roads carbon emissions by presenting and long and short term strategies. In which the research will replace streetscape elements with Smart-Streetscape elements that can be used for the short term strategy in lighting the neighbourhood's streets and public services but for the long term strategy it could be used to generate electricity for electric spencer that charging the electric vehicles.

The Secondary objectives

2. Creating statistical equation for calculating and estimating the roads carbon emissions during the design phase.
3. Identifying the relation between traffic density, carbon emission and electricity consumptions.
4. Review previous projects used RE in urban context that can be integrated with Streetscape
5. Creating a relation matrix between streetscape elements and RE devices, showing the elements that can be integrated with RE devices.
6. Presents a Cross-Sectional survey for Streetscape & RE devices.
7. Presents streetscape elements framework and identifying the properties of different renewable energy devices.
8. Presenting, Defining and identifying a new elements called Smart-Streetscape elements (SSSE).
9. Presenting Smart-Streetscape elements database that identify its properties.
10. Creating a software called "SSSE" that is a user-friendly online application, which helps urban designers and architects in using Smart-Streetscape elements instead of regular streetscape elements.
11. Helping in solving the global problems by generating clean energy using renewable energy devices in neighbourhoods, districts and cities instead of fossil fuel energy.
12. Proposing a short and long term strategy for solving the global environmental problems by reducing the road carbon emissions and generating clean energy from renewable devices.
13. Explaining the effect of Smart-Streetscape elements toward energy consumption and carbon emersion reduction.
14. Apply Smart-Streetscape elements in a pilot project to estimate its efficiency.

1.4. RESEARCH QUESTIONS

The main question of this research is how to generate renewable energy and reduce the roads carbon emissions using Smart-Streetscape elements?

The Secondary questions

1. What is the properties of Smart-Streetscape elements?

   Answered in Chapter 4 section 4.3
2. How to calculate CO_2 emissions from roads using the carbon emission model?

   Answered in Chapter 4 section 4.2
3. How can this research helps in solving the Egyptian energy crises by generating renewable energy in Egyptian cites instead of using fossil fuel?

   Answered in Chapter 5 section 5.4.6

1.5. HYPOTHESIS

The hypothesis of this research is that the high level of carbon emissions produced in Egyptian roads is from electricity production and the heavy use of vehicles and tucks for fossil fuels. Integrating Streetscape elements with RE devices will create Smart-Streetscape elements (SSSE), in which it will produce clean and efficient energy that can be used for lighting the neighbourhood's streets and public services, that will decrease the energy taken from the government in a short term strategy. But for long term strategy, it could be used to generate electricity for electric spencer that charge the electric vehicles. The short term strategy will decrease the carbon emissions produced from generating electricity while the long term strategy will decrease the carbon emissions produced from vehicles and trucks as shown in figure [1-6].

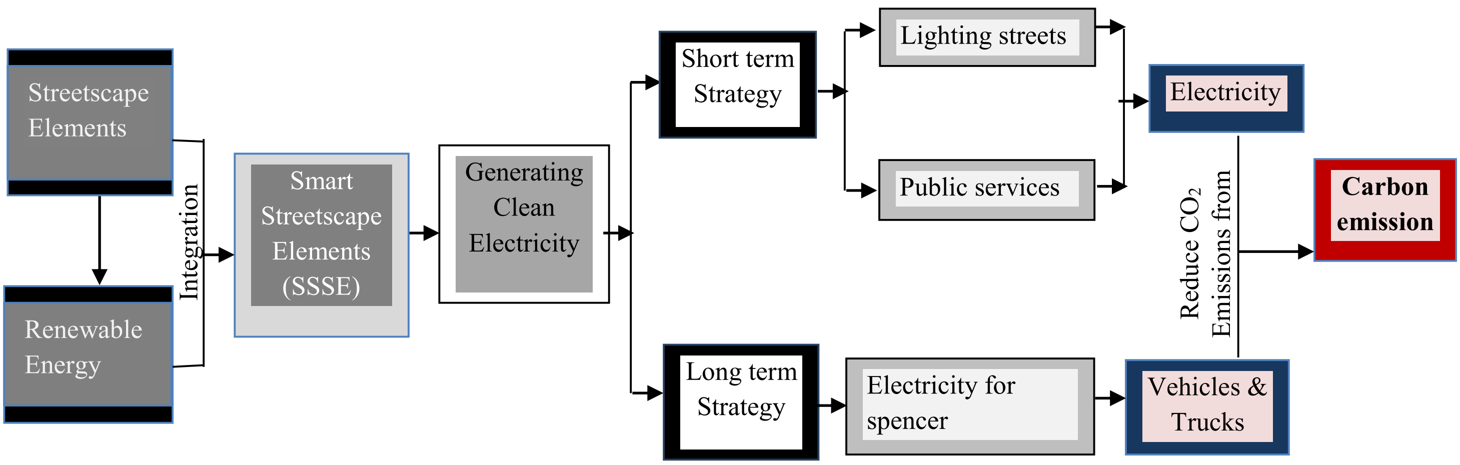


Figure [1-6]: Graphical abstract

1.6. METHODOLOGY

This research consists of two parts; theoretical and empirical. The theoretical part introduces the carbon emissions problems worldwide and it presents its negative impact toward human life and public health. Moreover, the literatures presents streetscape elements and it introduces renewable energy sources, as well as it provides information regarding the recent development schemes and the overall climatic conditions to identify new ways to generate energy from streetscape elements in the urban planning scale. This research considers the potential of renewable energy in the studied area.

The empirical part consist of two sections. The 1st section, creating a new statistical equation for calculating the carbon emissions from highway roads, taking into consideration the traffic density and the electricity consumption. While the 2nd section, creating a new online application called "SSSE", the software will integrating renewable energy devices with streetscape elements and present the Smart-Streetscape elements. This software will be used to locate the most suitable places for using Smart-Streetscape elements and it will calculate the amount of energy produced from each Smart-Streetscape elements used, the initial cost of installing this elements, the area needed to operate efficiently and finally it will present the life time and annual maintenance cost of each element. In addition to that, it will provide the user with a bubble diagram suggesting the most suitable location for installing each Smart-Streetscape element.

The research will present a theoretical implementation for the two empirical sections in a study area (El-Sherock city), and the results will explain the benefits and constrains of using the proposed elements (SSSE element) toward energy generation and CO_2 reduction, in which it effects the creation of sustainable neighbourhood.

Renewable energy device will be integrated with streetscape elements and Smart-Streetscape element will be presented as a tool for reducing the CO_2 emission from roads. In which it will solve the infrastructure problem facing the spreading of electric vehicles industry in Egypt. The research will provide two strategies for CO_2 reduction one on the short term by reducing CO_2 from generating electricity to light the roads and public facilities. While the other, long term strategy for providing infrastructure and power supply needed for charging the electric vehicles.

1.7. OUTCOMES:

The expected outcomes of this research can be divided into four main outcomes; the first outcome is a statistical equation for calculating carbon emissions in roads.

The second outcome is defining, presenting and identifying the properties of new sustainable elements called “Smart-Streetscape elements (SSSE)” that generate clean and efficient energy without compensating the functional role of streetscape elements.

The third outcome is “Smart-scape online application”. The research will introduce a new online application that presents the elements and properties of the Smart-Streetscape elements. The intention behind creating “SSSE” is to simplify the design process of designing Smart-Streetscape elements and to encourage the Egyptian designers in implement Smart-Streetscape elements in their project. The software will specify the SSSE elements that can be implement in a specific project and the software will suggest the location of each Smart-Streetscape element inside the project, in addition to that, the software will present the cost of installing the elements as well as the amount of energy produces. In which the software will facilitate the designing process and overcome the basic knowledge toward the properties of renewable energy devices that the Egyptian streetscape designers, architect, landscape architect and urban designers are facing. The research create the software to insure the sustainability of using Smart-Streetscape elements

The final outcome is measuring the efficiency Smart-Streetscape elements by applying this new elements in existing new urban settlement “El-Sherocuk City, Cairo - Egypt” and calculating the energy produced and CO_2 reduction from using this sustainable elements on the short term strategy.

1.8. RESEARCH STRUCTURE

The structure of this research is divided into two parts; the theoretical and empirical parts.

The theoretical park will be covered in chapter two and three. This part will identify the CO_2 problem worldwide and it will focus on Egypt our study area. In addition, it will present the different sources of renewable energy and streetscape elements to give the reader the necessary background on the research before the implementation part as shown in figure [1-7].

The second part in this research is divided into two chapters; chapter four (the empirical work) and chapter five (the case study). In the empirical chapter; the SSSE will be identified and its properties will be presented. Moreover, SSSE software will be presented along with CO_2 calculation model as shown in figure [1-7].

Finally chapter five, the case study chapter; in this chapter the research implementing the methods, model, equipment's and techniques used in a real study area located in Egypt. The empirical work that was explained in chapter four will be implemented in El-Sherock city, one of the new urban settlement in Egypt as shown below in figure [1-7].

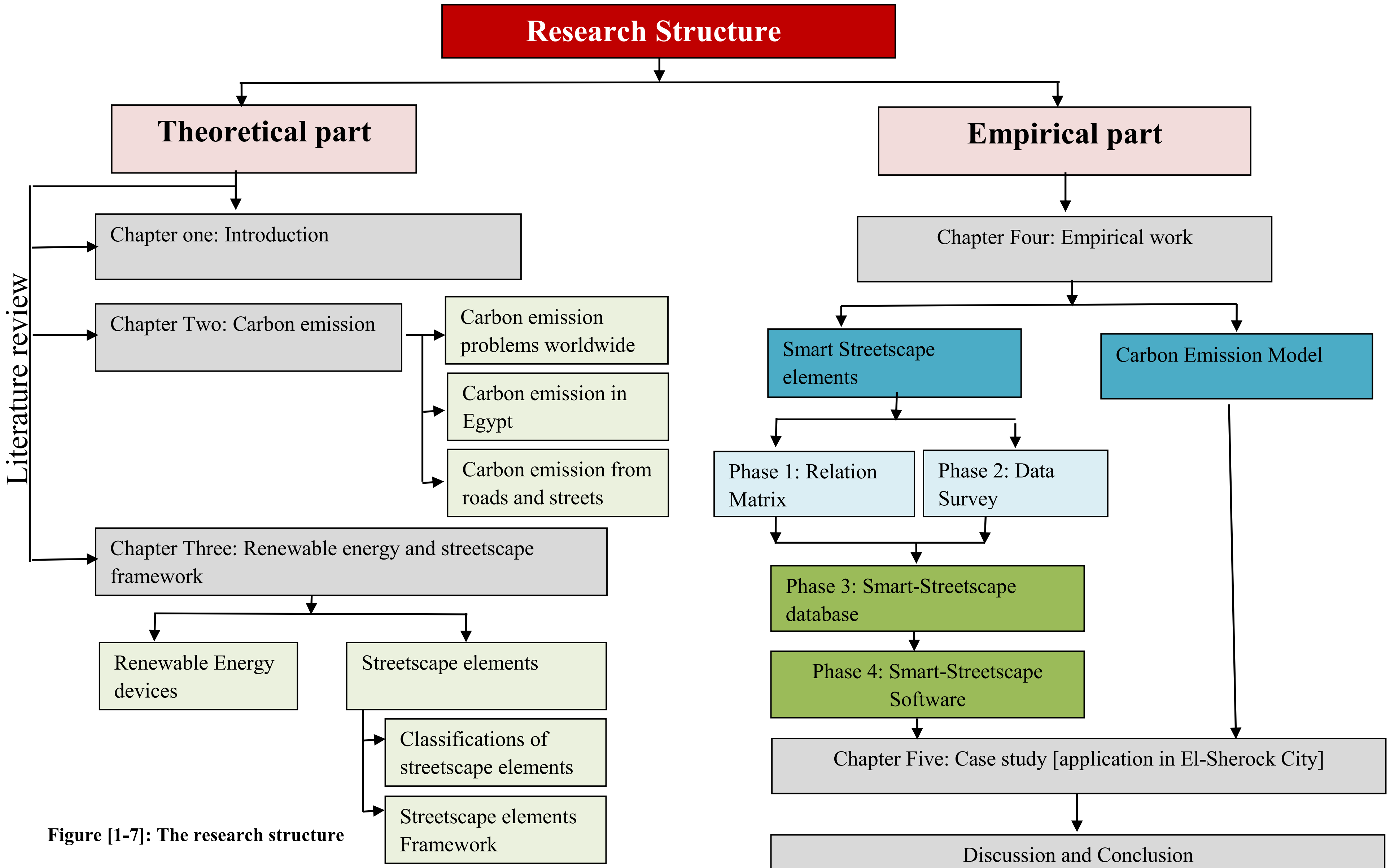


Figure [1-7]: The research structure

CHAPTER TWO

CARBON EMISSIONS

2.1. INTRODUCTION

Carbon Dioxide (CO_2) is a gas produced during combustion, fermentation and respiration. It has no color, no odor and nonflammable. CO_2 accumulates near the ground because it was proven to be 1.5 times heavier than air (Permentier, Vercammen, Soetaert, & Schellemans, 2017, pp. 1-4)

Since the Industrial Revolution, a rapid increase CO_2 happened due to consumption of fossil fuel. This has led to many problems as this disturbs the global carbon cycle. This disturbance is basically leading to a planetary warming impact. This huge consumption brings about the generation of carbon dioxide (CO_2), and since it is a gas that absorbs and emits thermal radiation, it creates the 'greenhouse effect', Along with other greenhouse gases. The effect of global warming ranges from ecological, physical and health impacts, including extreme weather events (such as floods, droughts, storms, and heatwaves); sea-level rise; altered crop growth; and disrupted water systems (Ritchie & Roser, 2017).

Global energy-related CO_2 emissions increased by 1.7% in 2018 to reach its peak of 33.1 gigatons (Gt) CO_2. This was the highest recorded growth rate, and 70% higher than the average increase since 2010. The main reasons behind this drastic raise is the higher energy consumption resulting from a booming global economy, and the high-energy demand needed to heat or cool some countries (IEA, 2018).

This chapter introduce the carbon emission problem worldwide and it focuses on the carbon emission produced from the roads in Egypt, specifically. The chapter defines and presents the causes of carbon emissions and how it effects negatively the public health.

2.2. THE GLOBAL SITUATION OF CARBON EMISSIONS AND AIR QUALITY

Over the past two centuries, mankind has increased the concentration of CO_2 in the atmosphere from 280 to more than 380 parts per million by volume, and it is still increasing every day. The electricity generation sector shared with approximately 40% (12Gt) of the global CO_2 emissions, produced from the combustion of fossil fuels (coal, oil, and natural gas) to generate heat that is used to power steam-driven turbines. Carbon dioxide is the primary cause of heat trapping which is known as "greenhouse gas". Heat trapping or Greenhouse is responsible for global warming, in addition to other nitrogen and sulfur oxides responsible for various environmental impacts such as ozone depletion and climatic changes (EIA, 2017; Abdallah and El-Shennawy, 2013, pp.1-8). Figure [2-1] shows the increase of Carbon emissions and the expected raise by 2030 (CDIAC, 2017)

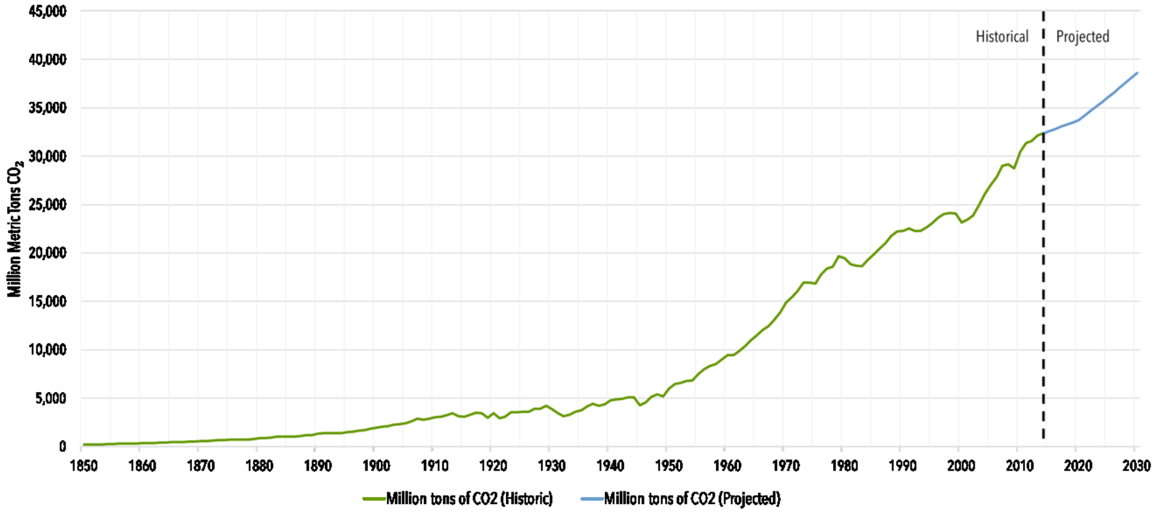


Figure [2-1]: Global Carbon Dioxide Emissions, 1850–2030
Source: (CDIAC, 2017)

The high concentration of CO_2 in the atmosphere effects the planet average temperature. Over the past century, the average surface temperature of Earth has increased by about 0.74°C. If Earth continue to emit carbon without control, the surface temperature is expected to rise by an additional 3.4°C by the end of this century. The climate change of that magnitude would likely have serious consequences for life on Earth (Abdallah and El-Shennawy, 2013, pp.1-8).

The continuous raise in temperature and the climate change is expected to have far-reaching, long-lasting and, in many cases, devastating consequences for planet Earth, such as increasing the sea level, droughts, floods, intense storms, forest fires, water scarcity and the appearance of cardiorespiratory diseases. There is also another risk, the continued warming will push the planet to "extreme weather events", other than hot and cold extreme weather conditions, it can also affect hurricane formations, percentage of lighting and rainstorms (Bradford & Pappas, 2017).

Despite the evidence of dangers caused by climate change, efforts to limit carbon emissions remain insufficient, ineffective, and, in most countries, non-existent. Given the current carbon emissions circumstances, and the best available scientific evidence, Carbon emissions need to be reduced by almost 80% of the total percentage by the year 2050. (DOE, 2010, pp.1-172; Abdallah and El-Shennawy, 2013, pp.1-8). According to the world resources institute, globally, the main sources of CO_2 emissions are electricity and heat (31%), agriculture (11%), transportation (15%), forestry (6%) and manufacturing (12%). Energy production of all types accounts for 72 percent of all emissions. Electricity sector shares with approximately 31% of the global CO_2 emissions, it is followed by transportation and industry. As shown in figure [2-2], the global CO_2 emissions, divided by sectors.

(Center for climate and energy solutions, 2017)

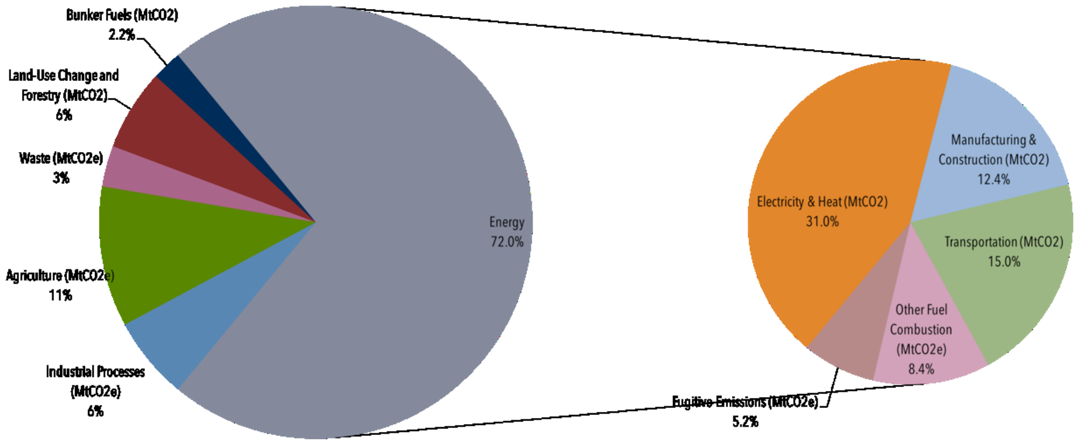


Figure [2-2]: The global CO_2 emissions by sectors
Source: (Center for climate and energy solutions, 2017)

In figure [2-2], the electricity is considered the highest contributor, as it is generated by coal-fired power plants and natural gas-fired power plants which overload the environment by carbon emissions.

In the United States, electricity produces more than one third of the U.S global warming emissions in which coal-fired power plants produces approximately 25 % of the U.S global warming emissions and the natural gas-fired power plants contribute with 6 % of the total emissions (EIA, 2017). Edward Mazria recognized the importance of having a clean and healthy environment, so he established an organization named "Architecture 2030" and then it started to be called "architecture 2030 challenge" the main goal of this organization is to consider solutions for decreasing the level of carbon dioxide and global warming emissions. "ARCHITECTURE 2030" issued a challenge between new developments, towns, neighborhoods, cities and regions to be carbon neutral by 2030 (Mazria, 2019). The aim of the challenge is to set a target plan for reducing the carbon emissions or greenhouse gases by 2030 as shown in figure [2-3]:

1- 80% in 2020
2- 90% in 2025
3- Carbon neutral in 2030

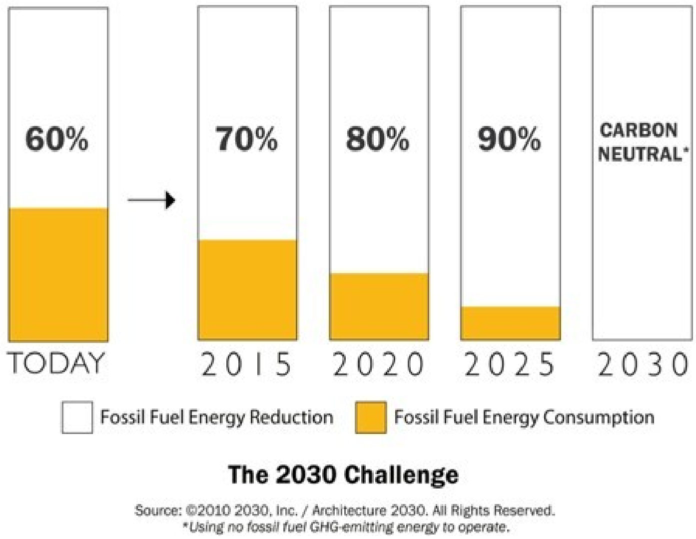


Figure [2-3]: The consumption and reduction of fossil fuel
Source: (Mazria, 2019)

These targets could be achieved through applying sustainable design strategies and generating electricity using renewable energy sources.

The development of renewable energy over the past decade has exceeded all expectations. Global installed capacity and production from all renewable technologies have increased drastically, and supporting policies have continued to spread to more countries in all regions of the world (Lins et al., 2014, pp 21-39).

When it comes to applying a renewable energy source, USA, China, Canada, Brazil and Germany were from the first countries that used hydropower in generating electricity. Currently China, Brazil and Canada are the top three hydro electricity producers worldwide, with 694.0, 429.6 and 376.5 TWh generated, respectively (Abolhosseini, Heshmati, & Altmann, 2017, pp.1-36). The countries must take advantages of their natural resources. For example, Netherlands has essential natural resources such as wind, the government of Netherlands depends too much on wind turbines to generate electricity with no carbon emissions. Moreover, in the golf area, the solar radiation is high and directly, so they depend too much on solar power to generate electricity as shown on table [2-1] (Abdallah and El-Shennawy, 2013, pp.1-8).

Table [2-1]: Comparison between different Renewable power plants in 2009
Source: (Abdallah & El-Shennawy, 2013)

	Hydroelectric	Photovoltaic	Solar-thermal	Wind farms
Electricity generation (TWhr)	3,288	12	1	219
% of total generation	16.2%	0.06%	0.005%	1.1%
Limitations	Implemented only at rivers or water falls	Low output power, depends on sun shining	Sun trackers require complex controllers	Wind speed must be >20 km/hr, noisy

The global estimated CO_2 emission from the electrical power industry is about 12 billion tones/ yearly in 2010, with approximate shares of 25% comes from USA, 25% comes from China, 25% comes from other major industrial countries, and 25% comes from the rest of the world. Egypt comes in the 30th place. Which produce approximately 64 million tons of CO_2 emissions/ year from electrical power plants (approx. 0.5% of global emissions) (UNFCCC, 2010, pp. 1-137)

2.3. THE CURRENT SITUATION IN EGYPT

In 2009, Egypt depended heavily on coal as the main source of electricity generation as shown in table [2-2]. Egypt is planning to increase the contribution of renewables in generating electricity, to reach total of 20% of energy generation by 2020, where hydropower represents 5.8%, wind 12%, and 2.2% from solar energy (Abdallah and El-Shennawy, 2013, pp.1-8).

Table [2-2]: Fuel Consumption for generating electricity in Egypt

Total fuel consumption in thermal plants	24700 ktoe
Total energy generated from thermal plants	119 TWhr
Fuel consumption rate	208 gm/kWhr gen.
CO_2 emission from thermal power plants	64 MMt
CO_2 emissions intensity	540 gm CO_2/kWhr gen.
CO_2 emissions per person (annually)	0.75 tons/person

Hydropower is considered one of the cheapest and cleanest sources of power generation in Egypt. Since 1985 to around 1995, hydro-power had contributed between 28 to 22% of the total energy produced by Egyptian power-plants, while the contribution of the hydro capacity was between 32.4 and 21.5% (Rashad & Ismail, 2000, pp. 285-302). Many studies have been carried out on the impacts of the Aswan High Dam on various aspects of the environment. The construction of Aswan High

Dam with a 2.1GW capacity in the 1960s was a renowned engineering project of the 20th century. Currently, over 85% of the Nile's hydro power potential has already been used (Abdallah and El-Shennawy, 2013, pp.1-8). The Electricity Ministry of Egypt is planning to build the first hydropower plant in the Middle East at a capacity of 2,400 MW using the pumped-storage hydropower (PSH) technology at Ataqa Mountain, Red Sea, to utilize renewable energy resources, Electricity Minister Mohamed Shaker said (Al Masry Al Youm, 2018).

Some of the world's best wind resources are located in Egypt, especially in Gulf of Suez, and West and East Nile valley due to high wind speeds ranging between averagely 8 and 10 m/s, and also due to the availability of large un-inhabited desert areas (GWEC, 2011, p.72). Figure [2-4] shows Egypt's wind atlas (Mortensen, Said, & Badger, 2006, p. 13). Currently, Egypt generates about 550MW of electrical energy from Zafarana wind farm located on the Gulf of Suez coast, along the Red Sea coastline and planning to generate 12% of its power from wind farms and a total of 20 percent from renewable sources by 2020 (AEE, 2009).

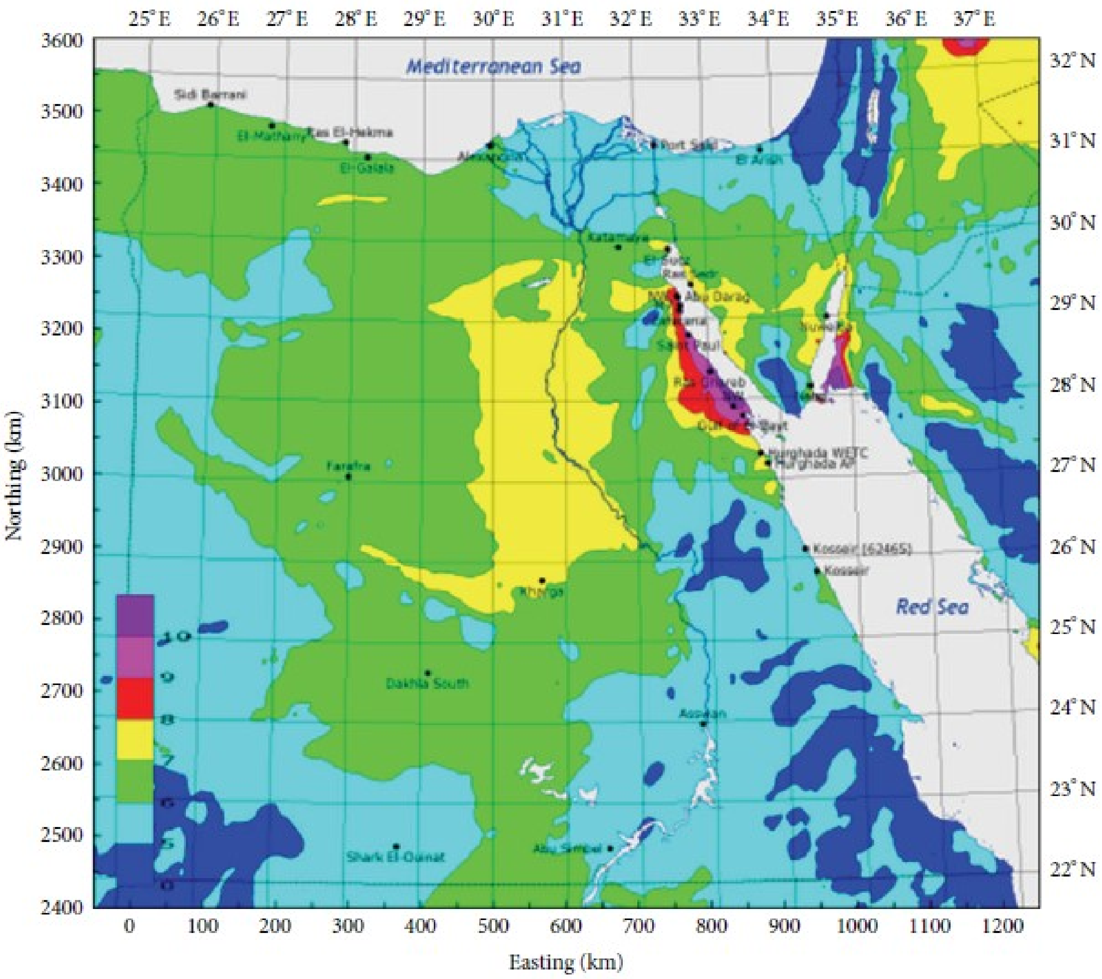


Figure [2-3]: Wind speed in Egyptian cities
Source: (Mortensen et al., 2006)

There is a large potential for renewable resources in the Middle East which, have remained largely not used. There is a very high potential for using solar energy in Egypt and its exploitation is critical for national sustainable development through efficient energy planning and a gradual independence from fossil fuels (NREA, 2018, p.26). This is especially true of solar power; its potential in the MENA region alone far exceeds global electricity demand. The high intensity of direct solar radiation (2,000– 2,600 kWh/m^2) in Egypt provides great potential for solar energy development, especially in Upper Egypt (Knies et. al., 2009, pp. 1-34; Muhammad, 2014, p.5). Solar energy is one of the most effective renewable resource and therefore much of the focus on sustainable energy is targeting the optimum solar energy. By 2050, the MENA Energy Policy Plan aims to limit climate change by capping the global temperature rise to no more than 2°C. For this reason, there is a possibility for a reduction of Green House Gas (GHG) emissions in Egypt by 80 - 95%, hence establishing a goal of 50% of primary energy from renewable origin by 2020 (NREA, 2018, p.22). Figure [2-5] shows Egypt's solar radiation measured in possible production of kilowatt hours per square meter per day (NREA, 2018, p.31).

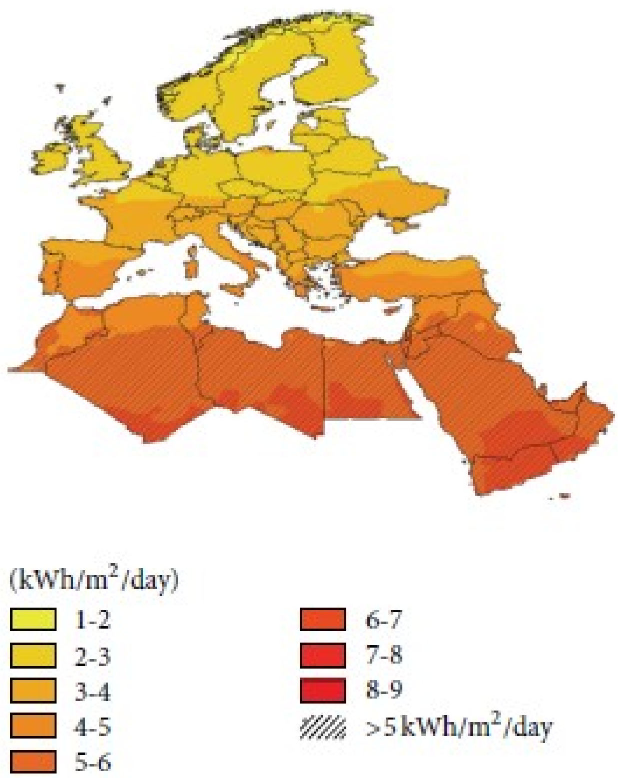


Figure [2-4]: Solar radiation measurements in Egypt
Source: (NREA, 2018, p.31)

2.4. AIR QUALITY IN EGYPT

The climate in Egypt is an important factor in increasing the intensity of air pollution. Geographically, being in a hot-arid climate where precipitation rarely occurs and surface winds are inactive almost all the year round. Moreover, heat reflection, resulting from seizure of pollutants within the air layer in contact with ground surface, causes episodes of acute air pollution, especially during autumn, commonly known as "the black cloud" (EEAA, 2005; Nasralla, 2001, p.p. 20-58)

There are numerous sources of air pollution in Egypt, as in other countries. However, the formation and levels of dust, small particles and soot are more characteristic in Egypt than presently found in industrialized countries. Some of the sources for these pollutants are industries, open-air waste burning and transportation. Cairo is considered one of the most polluted cities due to the rapid urbanization, industrialization and the growing number of vehicles (Hassan, 1999, p.68). The most recent air pollution “episode” occurred during autumn 1999 and early winter 2000 (October 1999 – January 2000). Consequently, an air quality management program based on scientific basis became an urgent matter to conserve air quality in big industrial and urban centers of Egypt.

However, it was found through the application of the environmental pollution Law 4/1994 during the last few years that the executive regulation should be revised and improved to meet the requirements of air quality improvement (Loeb & Nasralla, 2001, pp.1-32). The current air pollution situation should be reviewed and properly evaluated in order to set a realistic control strategy. Consequently, applicable emission standards can be attained on practical (Loeb & Nasralla, 2001, pp.1-32).

One of the sources of air pollution in Greater Cairo is burning the solid waste. Vehicles, including motor-bikes, are the major source of air pollution. Almost two thirds of carbon monoxide and 50% of hydrocarbons and nitrogen oxides that pollute the air are attributed to fuel combustion. Industrial zones, especially in Greater Cairo (Helwan, Shoubra Elkhaima and El Tibbeen) and numerous other areas abound in various industries, in addition to widespread small industries within the populous mass (EEAA, 2005). The amount of incinerated solid waste in Cairo is about 700 thousand tons to one million tons every year. Activities surrounding Greater Cairo are affecting the air quality. These include the burning of agricultural waste in the delta Nile valley during the autumn season; Industrial activities in the north of Greater Cairo in “Kaliob, Mustorod and Abu Zaabal” districts include iron and steel, chemicals, phosphate fertilizers, petroleum refineries, clay bricks, smelters, foundries, steel work, boilers (food and textile industries) and many other small activities. Other industries located west the Greater Cairo include brick industries along the western bank of river Nile, north and south of Giza governorate, sugar and allied chemicals at Hawmedia; wood industries, smelters, chemical industry, and other small industrial activities at Abu Rawash and the industrial area west of Giza. Mining, lime work and stone quarrying at Mokkatum, Katamia, Tora south of Cairo as well as sand quarrying S-W of Giza. Moreover, the air quality of Cairo is affected by natural causes such as dust carried out by wind from the surrounding desert and hills (Loeb & Nasralla, 2001, pp.1-32).

Air pollution is a high priority in the development agenda of the government of Egypt due to high levels of local pollutants experienced in dense cities. In Cairo Air Improvement Project (CAIP), a Source-Attribution-Study (SAS) was conducted between 1997 and 2004 to identify the contribution of various sources to air pollution in Egypt. The study revealed that vehicle exhaust accounted for 32% of air pollution indicated by particle matter (PM10 and PM2.5) in air as shown in figure [2-6] (Hamed, et al., 2013). This also implies the high contribution with other contaminants such as sulfur oxides (SOx), nitrogen oxides (NOx) and volatile organic compounds (VOCs) which in the case of vehicle exhausts are emitted with fine particle matter. The study also revealed the truth about natural sources such as sand and soil dust claimed to be the main source and indicated how the transport sector is a priority in addressing air pollution (El-Dorghamy, 2015, p.1-26).

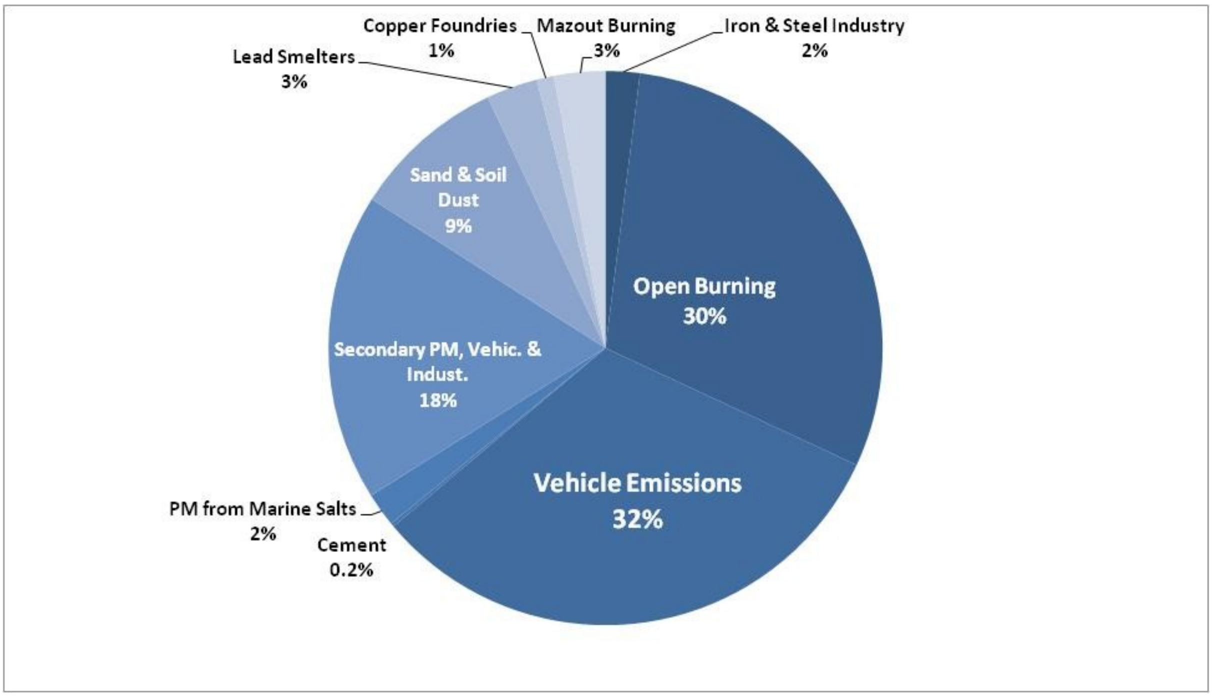


Figure [2-5] Air pollution in Cairo divided into sectors

Source: (El-Dorghamy, 2015)

Other researches also confirmed that vehicle exhaust is the dominant source of various pollutants in Cairo such as black carbon (BC) and the carcinogenic VOCs, benzene, toluene, ethylbenzene and xylenes (BTEXS), and hydrocarbons (HCs) in street dusts. The Egyptian government has adopted several procedures for reducing Greenhouse Gas emissions from the transportation sector; including improving the public transport, improving fuel efficiency of vehicles, and monitoring on-road vehicle emissions, among other measures. However, the translation of strategies into plans and practical implementation has not been assessed (El-Dorghamy, 2015, p.1-26).

2.5. CARBON EMISSION IN EGYPT

Energy is considered Egypt's Greenhouse gases dominant sector. Within this sector, electricity and heat production is responsible for 41%, transportation 24%, manufacturing and construction 17%, other fuel combustion 11%, and fugitive emissions 7% of energy sector GHG emissions as shown in figure [2-7] (USAID, 2015).

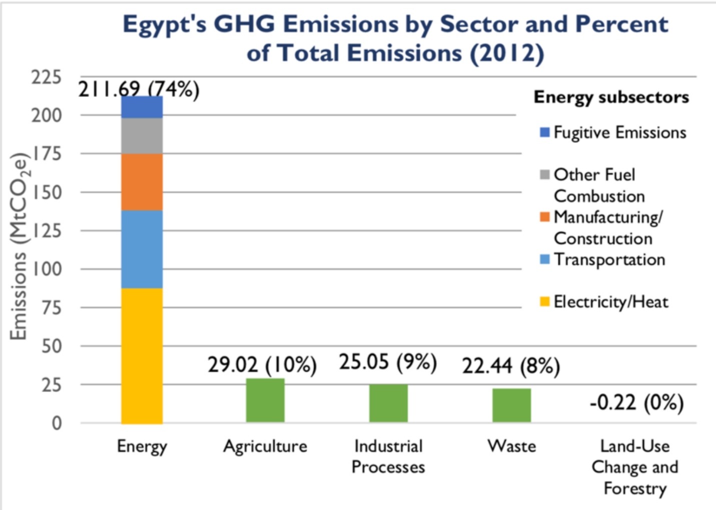


Figure [2-6]: Egypt's GHG emissions by Sector and Percentage of Total Emissions
Source: (USAID, 2015)

According to the International Energy Agency (IEA), it was concluded that between 1990 and 2012, Egypt's total primary energy supply more than doubled during this time, with fossil fuels accounting for 94% and renewable energy sources with only 4% in 2012 as shown in figure [2-7].

Egypt's heavy reliance on hydrocarbons is expected to continue to increase with continued social and economic development. The Rapid growth in energy demand is driven by urbanization, increased industrial output, energy-intensive industries, motor vehicle sales, and energy subsidies. Emissions from the transportation sector are the fastest growing, due to heavy reliance on roads and motor vehicles as the primary means of transport.

2.5.1. Transport: The Vehicles contribution

Egypt is considered the largest Arab country, with a population of more than 90 million people which makes it the second most populous country in Africa. According to research in 2013, the total number of licensed vehicles in Egypt were 7.04 million vehicles, and about 50% of them are in the Cairo. Almost half of all vehicles in Egypt are cars, specifically 3.83 million cars. The distributions of the types of vehicles are provided in Figure [2-8] (CAPMAS, 2013).

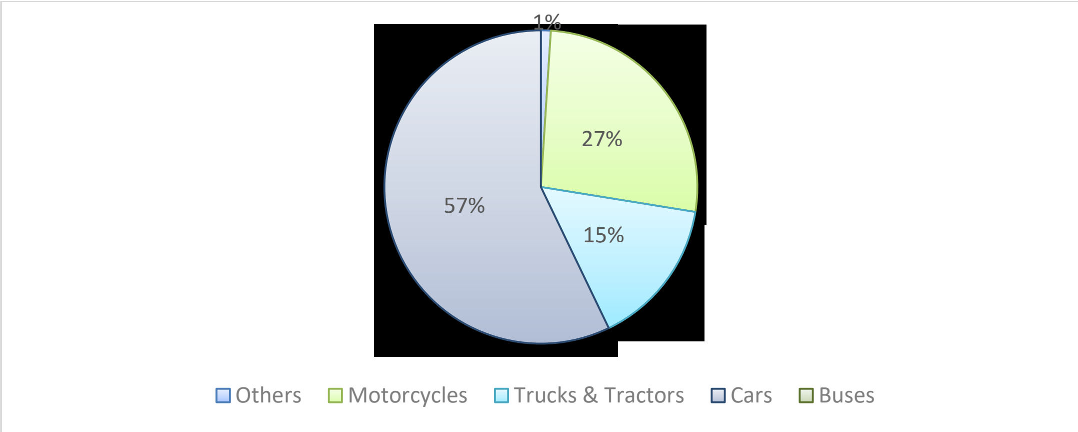


Figure [2-7]: Vehicle stock in Egypt
Source: by author

Between the years 2003-2004; the amount of people transported by roads were around 115.6 billion passenger/km, where the freight transport amounted to around 43.1 billion tons/km. In Egypt, the transportation sector has a huge share of the countries Greenhouse gases due to the heavy use of fossil fuels. In 2004, the transportation sector shared with an average of 29.16% of the overall energy consumption in Egypt. Moreover, it produced around 31.6 million tons of CO_2 Emissions which is approximately 26% of the total Co_2 emissions produce from energy generation. The more the population grows, the more the need for energy in the transportation sector will be needed (Ahmed, 2015, pp. 1-35). Table [2-3] presents the average number of passenger in each transportation sector between year 200-2003 and year 2003-2004.

Table [2-3]: the Egyptian transport Indication
Source: (Ahmed, 2015)

Indicator	2002-2003	2003-2004
Railways		
Million Passenger/ Km	46,185	76,090
Million Ton/ km	38,444	4,758
Railway length (km)	9,432	9,467
Roads		
Million Passenger/ Km	113,570	115,845

River Transport		
Million Ton/ km	309	2,375
Pipeline Transport		
Million Ton/ km	6,489	6,680

2.6. THE EFFECTS OF CO_2 EMISSIONS

Carbon emissions contribute to climate change, which can have serious consequences on the environment, consequently, on humans. The problem is that After CO_2 is emitted into the atmosphere, 40% will remain in the atmosphere for hundred years and 20% will reside for thousand years, while the final 10% will take years to turn over. This means that the heat-trapping emissions released today from the vehicles and the other mentioned sources are setting the climate the future generations will inherit (UCSUSA, 2017).

2.6.1. Acid Rain:

Acid rain is the term given to increased acidity of rain as a result of gases (from industrial and natural processes) which dissolve in rainwater to form various acids. The effect of Carbon emissions is of concern as it dissolves in rain, converting into weak acid, aka Carbonic Acid (Mehta, 2010). The acidity spreads through wet and dry deposition. Wet deposition is the most common form of acid rain which usually falls in the form of rain, snow, fog, or hail. While Acidic particles and gases can also deposit from the atmosphere in the absence of moisture as dry deposition. “The acidic particles and gases may deposit to surfaces (water bodies, vegetation, buildings) quickly or may react during atmospheric transport to form larger particles that can be harmful to human health. When the accumulated acids are washed off a surface by the next rain, this acidic water flows over and through the ground, and can harm plants and wildlife, such as insects and fish. The amount of acidity in the atmosphere that deposits to earth through dry deposition depends on the amount of rainfall an area receives. For example, in desert areas the ratio of dry to wet deposition is higher than an area that receives several inches of rain each year.” (EPA, 2019). Acid rain affects both, the ecosystems and human health. As for the ecosystem, acid rain affects ponds, rivers, streams, lakes, gulfs, seas and oceans by increasing their acidity, disturbing the marine life. The pH value between 5 and 8 is the ideal pH range for the plants’ growth, and out of these ranges in soils, plants face difficulties to germinate or grow. No plants grow if pH is less than 3.7, thus, plants are affected directly by reducing the PH. For the human health, the dissolved gases from acid rain create eye, nose, and throat irritations, and lung disorders, such as dry coughs, asthma, headaches, and bronchitis. The discharge toxic metals due to acid rain are absorbed by the water, crops, or animals that human consumes that cause severe nerve damage, lung problems, brain damage, kidney problems, cancer, and Alzheimer's disease, that may cause death (Mohajan, 2018, pp. 8-10).

2.6.2. The Rise of water level

Egypt's Carbon emissions rate makes it extremely vulnerable to climate change. Moreover, its densely-populated Nile delta is seriously threatened by sea level rise. Vulnerability assessment studies in priority sectors have been done as part of the development of the national action plan. The study results have indicated that the agriculture, coastal zones, aqua-culture and fisheries, water resources, human habitat and settlements, and human health are most susceptible in order of severity and certainty of results (UNDP, 2018). While other studies suggest that with the increase in global temperatures there will be increased evaporation in the Nile River and thus less water supply and ultimately water scarcity, Other studies concluded that with the increased evaporation in Egypt, that will result in increased precipitation in the Ethiopian highlands (more upstream from Egypt) which will lead to increased runoff in the Nile River flows downstream in Egypt (Hatow, 2015).

2.7. STREETS AND CO_2 EMISSIONS

In previous years, governments had less attention on the reduction of CO_2 Emissions which could be achieved by reducing traffic congestion in the Egyptian streets. Previous studies proved that when the congestion increase, the CO_2 Emissions automatically increases. That is the reason why, some guidelines are rules should be set and followed in order to reduce any amount of congestions. However, the challenge is in how big the Emission reduction could be when we reduce the congestions? Different factors exist; which includes the behavior of individual in driving, type of roads and vehicles and the condition of traffic; whether good or bad (Boriboonsomsin & Matthew, 2009, pp. 2-4).

Figure [2-9], shows the average emissions produced of different types of vehicles in (Lit/Km). The results showed that cars produce around 0.24 KG of CO_2 Emissions, a bus produce around 0.60 kg of CO_2 Emissions and a motorcycle produce around 0.10 kg of CO_2 Emissions in 1 km. However, some vehicles could differ depending on its weight, power and other factors.

Type of vehicles	V	R_D (km)	A_V (lit/km)
Bus	7800	250	0.25
Taxi	82358	185	0.1
Private Car	2400000	43	0.1
Motorcycle	560000	40	0.04

Figure [2-8] Mass Emission per Vehicle
Source: (Barth & Boriboonsomsin, 2009)

Researchers often uses the average speed of vehicle to measure the performance of traffic Previous studies also shows that if we take a large number of car trips and apply them to an emission model for a passenger car; a histogram for CO_2 Emissions will be conducted as in the figure [2-10] below which illustrates that Emissions can differ from one trip to another depending on many aspects (Barth & Boriboonsomsin, 2009, pp 5-8).

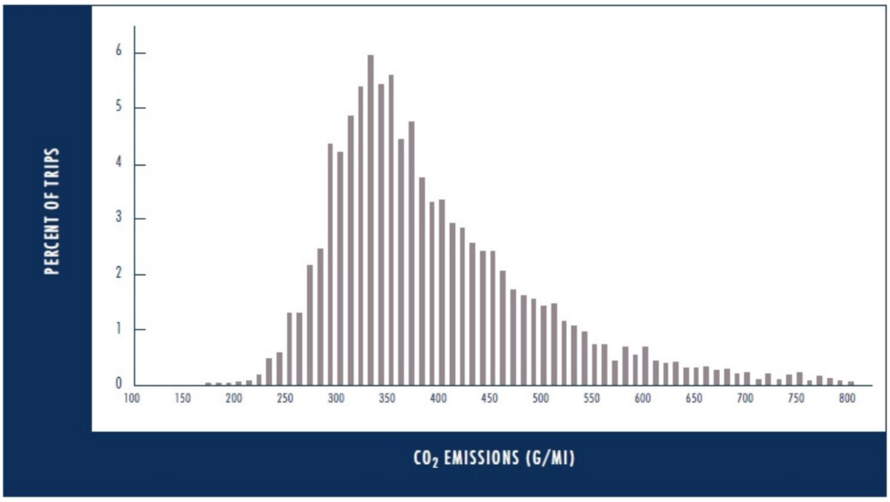


Figure [2-10]: percentage of trip vs. Emissions
Source: (Barth & Boriboonsomsin, 2009)

2.8. SUMMARY

The chapter presents the level of pollution in the world atmosphere and it focuses on the percentage of carbon emission, specifically in Egypt. Moreover, it presents the causes of increasing the carbon emission in Egyptian atmosphere and how it effects negatively the Egyptians public health along with the Ecosystem and without action to control emissions, the Carbon footprint will continue to rise, increasing the negative effects.

Egypt's long-term development goals promote renewable energy resources and energy efficiency which will reduce greenhouse gas emissions and support sustainable development. While one of the main contributors in increasing the percentage of CO_2 in Egyptian atmosphere is the roads and traffic and by focusing on this sector only, there will be a potential for reducing the Carbon emissions drastically.

CHAPTER THREE

RENEWABLE ENERGY AND STREETSCAPE FRAMEWORKS

3.1. INTRODUCTION

Renewable energy (RE) sources are best located as near to the point of use as possible i.e. in built up areas. Previous work has successfully explored the integration of renewable energy (RE) into buildings e.g rooftop Photovoltaic (PV) panels. A greater potential lies in utilizing open spaces in cities (the area between buildings) such as roads, pavements, hard streetscape etc.

The main scope of this research is to reduce CO_2 emissions using Smart-Streetscape elements (SSSE) which occurs from integrating renewable energy (RE) with streetscape elements. This chapter intend to present the different renewable energy (RE) sources, properties, materials and the ways of implementation in projects to give the reader a fully understanding towered these sustainable sources. Moreover, the chapter will also identify streetscape elements and properties to fulfil the main purpose of the research which is integrating renewable energy (RE) with streetscape elements.

3.2. RENEWABLE ENERGY (RE)

The current energy crisis has shifted human efforts towards using renewable energy (RE) sources. In the last fifteen years, the global renewable energy (RE) market has shown huge growth in technologies. In recent years, the competitiveness with conventional power plants has increased which has given additional impetus to the global market for renewable energy technologies (Kost et al, 2013, pp.1-50).

The computed result of using solar, wind, hydropower, geothermal and biomass shows that they can produce sufficient energy for supplying the world population more than a few times over. As the practical point there is only a small number of technologies for utilizing renewable energies have verified to be useful. While, the economic viability is bounded this technology to limited number of counties in the world. Frequently, markets are robustly altered by grant in keep of fossil fuel, put down renewable energies at a weakness (Boyle, 2012, pp.20-60; Jahankhani & Hosseinian-Far, 2011, pp. 1-7).

The early entry into the renewable energy (RE) technologies market, attempted to initiate a transformation process to an energy system based on renewable energy technologies and building of production capacities and installations of renewable energy technologies, and profit from their development on a macro-economic level. At the same time, more and more technological developments are being created, in which renewable energy technologies are also competitive without support for investments (Kost et al, 2013, pp.1-50).

This research will identify the properties, techniques and material used to install renewable energy sources such as solar energy, piezoelectric cells, wind energy, biomass energy, hydroelectric power and geothermal energy as shown in figure [3-1]

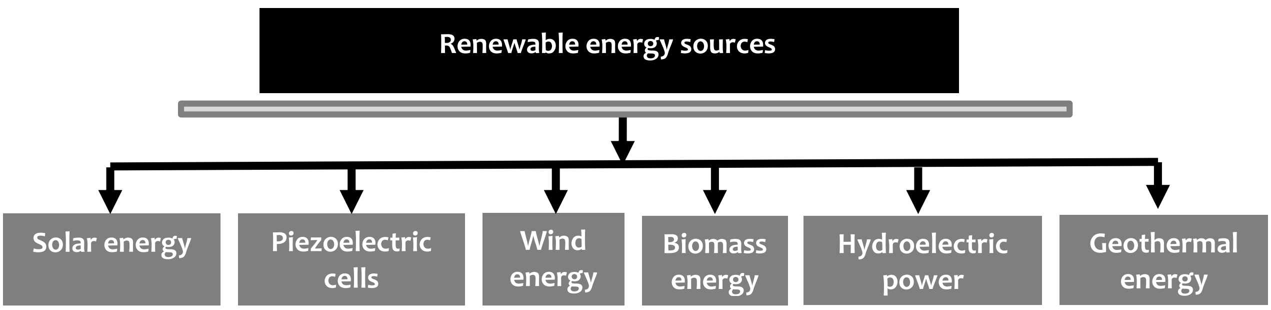


Figure [3-1]: Renewable Energy Sources

3.2.1. Solar Energy

Solar energy depends on the solar radiation that the sun delivers to the Earth every day to power global society. Solar energy has a potential to supply of 0.05% of to the global energy demands and it is considered a renewable energy (RE) source. The earth obtains 4.3×1020 joules of sun ray in an hour which could supply the request of the human demand in a year (Biello, 2008). Solar energy is more valuable in regions with high quality sunshine (Quej et al, 2017, pp.75–82.). Solar power can be classified into two categories: solar thermal which can be utilized to produce the heat and photovoltaic "PV" (Jahankhani & Hosseinian-Far, 2011, pp. 1-7).

3.2.1.1. Photovoltaic cell

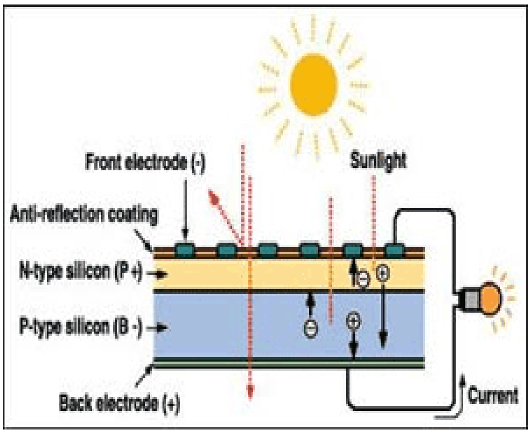


Figure [3-2]: Details of photovoltaic cell
Source: ENGINEERING.com, (2016)

Figure [3-3]: PV cells
Source: (Society Promoting Environmental Conservation, 2016)

Photovoltaic technology is improving and the cost is falling. Solar PV panels use the energy from the Sun to "excite" electrons into a high energy state, at which point they are converted into electricity (Butler, Lerch and Wuerthner, 2012, pp.1-384; ENGINEERING.com, 2016). Solar energy is distributed throughout the world, which means many remote populations can produce electricity without constructing inefficient, expensive, and habitat-disrupting long-distance-transmission infrastructure (Butler, Lerch and Wuerthner, 2012, pp. 1-384). Today, Photovoltaic is the most common application which is measure as the sustainable energy producer. (ENGINEERING.com, 2016). Photovoltaic technology is considered as a system which provides electricity without any pollution and can be set up in commercial and residential areas as shown in figure [3-3]; however it releases the greenhouse gas. The growth of Photovoltaic system has been 1.5 GW over 2005 especially in European countries such as Germany (Jahankhani & Hosseinian-Far, 2011, p.6). Solar PV offers numerous advantages over fossil fuels for generating electricity. Greenhouse gas emissions are considerably lower over the life of the panel, even when accounting for emissions during construction (Butler, Lerch and Wuerthner, 2012, pp. 384). The photovoltaic cell is quite strong, has cheap maintenance and is very valuable technology for the countries with affluent sunshine. (Jahankhani & Hosseinian-Far, 2011, p.5). The cloud cover, fog, seasonal light availability, and dust on the panels can affect photovoltaic electricity generation (Sherwani et al, 2010, pp.540–544; Butler, Lerch and Wuerthner, 2012, pp. 384). The standard PV solar silicon is made of two layers: phosphorus-doped (N-type) and boron-doped (P-type). The N-type silicon is located in top of the P-type silicon. The connection of these two silicones is called P-N junction and actually the electricity is created in this area as shown in figure [3-2]. The sunlight radiation on PV cell is causing momentum granted and light motivated electrons to generate electricity. The current output of PV depends on the size and strength degree of sun rays shining (Jahankhani & Hosseinian-Far, 2011, p.5; ENGINEERING.com, 2016).

3.2.1.2. Concentrated Solar Power

Concentrated solar power (CSP) uses a series of mirrors to focus the solar energy into one location where the heat is collected to make steam, the steam drives a turbine, which generates electricity. (Bilena et al, 2008, pp.1529-1561; Jahankhani & Hosseinian-Far, 2011, p.4). In CSP, the electricity generation process itself has zero emissions. There are emissions associated with the construction, maintenance, and decommissioning of the facility, but they are not compatible to the emission produced from coal or other fossil fuel-burning plant. Concentrated solar facilities do have a significant physical footprint and require adequate transmission infrastructure to get electricity to consumers. CSP plants cannot be built on public lands because their construction would negatively affect fragile desert habitat or endangered species. Proper siting on industrial brownfields near existing transmission lines would eliminate these negative impacts of CSP development.

Concentrated solar and solar PV-generated power both are relying on sunlight, they are intermittent sources of energy, which generally means that either natural gas or hydroelectricity must be used as a backup to offset the rapid fluctuations in power output from solar facilities. Additionally, cooling the steam produced at CSP facilities requires massive amounts of water, which is a scarce resource in the sunny, desert environments where CSP facilities are most efficient. On average, CSP plants consume as much water per megawatt of electricity generated as coal plants (Butler, Lerch and Wuerthner, 2012, pp.1-384).

There are three types of CSP plant, the first type is called a solar tower power CSP plant, the second type is parabolic trough while the third type is Linear Fresnel lens. The solar tower CSP plant which is known as “Gemasolar plant” use dual-axis tracking mirrors to reflect solar energy onto a central tower that contains a working fluid, usually molten salt. The salt is heated to temperatures of 300˚C or more and passed through heat exchangers that generate steam to drive turbines as shown in figure [3-4 $ 3-5] (Andrews, 2016).

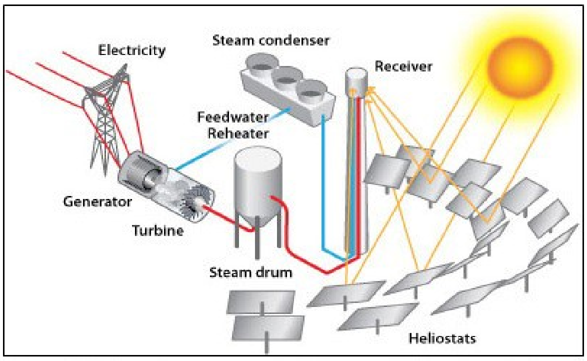


Figure [3-4]: Detail of Gemasolar plant is a solar tower
Source: (Andrews, 2016)

Figure [3-5]: Gemasolar 20MW CSP plant
Source: (Andrews, 2016)

The parabolic trough is the most common type of CSP plant. The parabolic trough had a linear single-axis of mirrors that concentrates solar energy onto a tube containing a fluid such as molten salt, located along the focal point of the mirrors, and the molten salt is used to generate steam to drive turbines as shown in figure [3-6; 3-7] (Andrews, 2016).

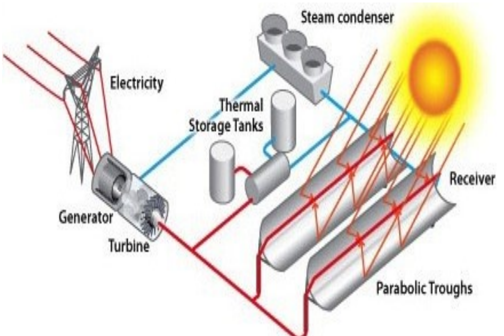


Figure [3-6]: Detail of single-axis tracking array, Andasol parabolic trough plant
Source: (Andrews, 2016)

Figure [3-7]: parabolic trough plant
Source: (Andrews, 2016)

Linear Fresnel reflector systems are similar to parabolic trough systems had a set of mirrors that reflects the solar radiation onto a linear receiver. The major difference is that with a Fresnel system the mirrors are either flat or slightly curved and are mounted on a tracker that focuses the sun light onto a fixed receiver tube system that sits above the mirrors as shown in figure [3-8] (Andrews, 2016). Linear Fresnel systems have lower production costs due to the use of flat mirrors compared to the curved mirrors used in parabolic trough systems. Another major difference is that water can be converted directly into steam in the long receiver tubes, eliminating the need to install additional heat exchange equipment.

Focusing the relatively dispersed energy from the Sun to produce electricity from steam is a high-tech way of capturing solar energy. Unfortunately, the places where concentrated solar technology works best in the deserts

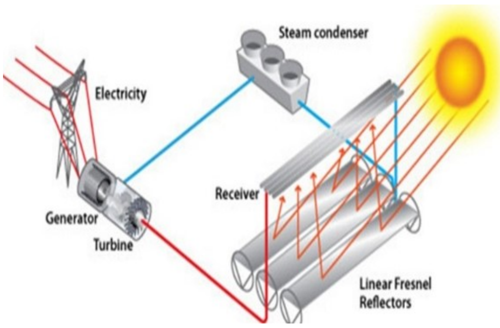


Figure [3-8]: Detail of Linear Fresnel
Source: (Andrews, 2016)

which is the places where water source is limited and its impacts on wildlife habitat, including for endangered species, is sometimes inevitable. The combination of PV technology, solar thermal technology has been a highly appealing option for developers and researchers since the late 1970s and early 1980s, the result is known as a concentrated photovoltaic thermal (CPVT) (Buffet, 1982, pp.251–256). Concentrated photovoltaic thermal (CPVT) solar collectors have been gaining ever increasing attention from the scientific community and industrial developers due to their promising potential to pave the way for the penetration of solar energy into modern day power generation technologies. CPVTs' flexibility, manufacturability, high efficiency, and multi-output nature inspired many innovative designers to improve it (Li et al, 2011, pp.2378–2383; Jahankhani & Hosseinian-Far, 2011, pp. 1-7; Zhao et al, 2011, pp.1343–1353; Quaia et al, 2012, pp.1130–1135; Kandilli, 2013, pp.186–196; Sharaf & Orhan, 2015, pp.1500–1565). CPVTs energy and greenhouse gas pay back periods as low as one year (Charalambous et al, 2007, pp.275–286; Zondag, 2008, pp.891–959; Singh & Othman, 2009, pp. 10-14; Chow, 2010, pp.365–379; Hasan & Sumathy, 2010, pp.1845–59; Avezov et al, 2011, pp.169–83; Cellura et al, 2011, pp.12; Chemisana, 2011, pp.603–611; Daghigh et al, 2011, pp.4156–4170; Ibrahim et al, 2011, pp.352–365; Kumar & Rosen, 2011, pp.3603–3614; Pérez-Higueras et al, 2011, pp.1810–1815; Baig et al, 2012, pp.5890–5909; Tyagi et al, 2012, pp.1383–1398; Zhang et al, 2012, pp.599–617; Sharaf & Orhan, 2015, pp.1500–1565).

3.2.2. Piezoelectric Cells

Piezoelectric materials are crystals that generate electricity when compressed or vibrated. They have the unique opposite property of generating a stress when voltage is applied to them (Hill, Agarwal & Tong, 2014, pp.1-93).

The first demonstration of piezoelectric effect was in 1880 by the brothers Pierre Curie and Jacques Curie. They combined their knowledge of pyro-electricity with their understanding of the underlying crystal structures that gave rise to pyro-electricity to predict crystal behavior, and demonstrated the effect using crystals of tourmaline, quartz, topaz, cane sugar, and Rochelle salt (Tiwari et al, 2012, pp.404-411).When force is applied to this sensor, the quartz crystals generate an electrostatic charge proportional to the input force. This output is collected on the electrodes sandwiched between the crystals and is then either routed directly to an external charge amplifier or converted to a low

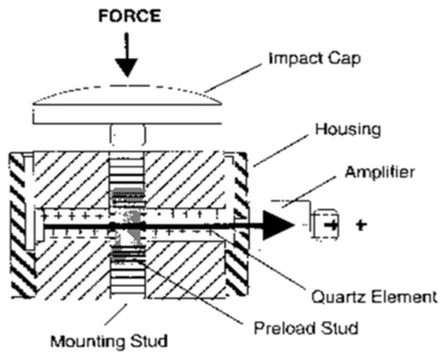


Figure [3-9]: illustrates the cross-section of a piezoelectric cells
Source: (PCB PIEZOTRONICS, 2016).

impedance voltage signal within the sensor as shown in figure [3-9] (PCB PIEZOTRONICS, 2016).

Piezoelectric materials fall within a class of multiple solid state materials as shown in figure [3-10] that can generate electricity with the application of some stimulus such as heat, stress, or light. Piezoelectric materials generate electricity with the application of stress (Hill, Agarwal and Tong, 2014, pp.1-93).

Figure [3-10]: Piezoelectric cells
Source: (Omega, 2016)

Using piezoelectric cells to harvest vibration energy from humans walking, machinery vibrating, or cars moving on a roadway is an area of great interest, because this vibration energy is otherwise untapped. Since movement is everywhere, the ability to capture this energy cheaply would be a significant advancement toward greater efficiency and cleaner energy production (Hill, Agarwal and Tong, 2014, pp.1-93).

This method transfer mechanical energy into electrical energy by straining or deformation of a piezoelectric material. Deformation of a piezoelectric material causes charge separation across the material, producing an electric field and consequently a voltage drop across it. This voltage drop is almost proportional to the stress applied. The voltage produced varies with time and strain, producing an irregular current. Piezoelectric materials can also be used in systems where it is subjected to stress or compression, producing a voltage of around 2~10V (Rahman, Sakir and Onna, 2012, pp.1-77).

Piezoelectric materials is easy to maintain. However, the material itself is not very available yet and it depolarizes easily causing less production of voltage at times, leakage voltage is high and it has high output impedance. It is used for harvesting vibration energy where stress or compression is available (Rahman, Sakir and Onna, 2012, pp.1-77).

There is two types of piezoelectric materials PZT and Quatz. PZT is the most efficient, as it is able to convert 80% of the mechanical energy into electrical energy. PZT is 100 times more efficient than quartz (Umeda et al, 1997, pp.3146-3151; Sodano & Inman, 2004, pp.49-58; Rahman, Sakir and Onna, 2012, pp.1-77; Tiwari, et al, 2012, pp.404-411).

3.2.3. <u>Wind Energy</u>

Wind power technology has been one of the fastest growing energy sources in the past 20 years. Today, wind power is harvesting the free power of the wind effectively and much more efficiently than ever before. Wind power is one of the most successful renewable energy resources, it plays a central role for the development of a sustainable electric power supply system (Allardyce, 2011, pp.1-73; Puglia, 2013, pp.1-73). But it does require backup systems to keep generating energy when the wind is not blowing. Today, wind turbines can be small and powering single homes or businesses, or large to power a thousand homes.

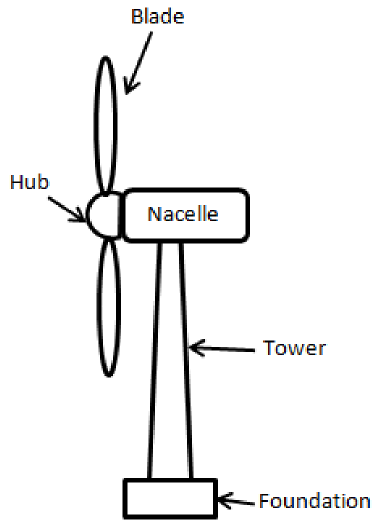


Figure [3-11] Main components of a wind turbine
Source: (Cantú, 2011)

The negative effects of wind turbines is on birds. In addition to that, other local complaints about the noise and shadow flicker from blades, and there are also some concerns toward the visual impact of the large facilities. Wind power tends to be best on mountaintops or offshore areas that can be tough to reach and may lack electrical infrastructure (Butler, Lerch and Wuerthner, 2012, pp. 384).

A wind turbine is a machine that converts kinetic energy from the wind into mechanical energy which is converted into electric energy. Once the construction and transportation is complete there are no pollutants released during energy production and no waste products from this source unlike fossil fuels and nuclear. Wind turbines are tall but only take up a small area of land therefore can easily be installed in many different areas (Puglia, 2013, pp.1-73). Due to the limited availability of lands and better conditions regarding social acceptance and subsidies, wind power development has been expanding to offshore sites. This allows larger turbines and wind farms. Along with the positive aspects, mainly the increased rated power, larger turbines and offshore wind farms also bring new thoughts to worry about, such as transportation vessels, adequate ports, weather windows, greater fatigue/loads and corrosion (Cantú, 2011, pp. 73; Kost et al, 2013, pp.1-50).

Wind turbine manufacturers and operators are still figuring out better strategies for the optimal operation and maintenance of the offshore wind farms around the globe. Although onshore wind energy is already being competitive with other sources of energy, the increased cost of construction for offshore wind farms (up to 50 % more) is not the only extra burden. Operation and maintenance costs are also increased for the offshore case, as specialized vessels, weather windows and rough conditions mean more failures, downtime (decreasing availability), spare parts, and man-hours (Cantú, 2011, pp. 73).

The electricity produced from wind energy, comes from horizontal axis, (HAWT). That is, the axis of rotation is parallel to the ground. The principal subsystem of a typical HAWT includes the rotor, drive train, generator, nascelle and yaw system, tower and foundation, and control system as shown in figure [3-11]. The main systems and components of wind turbine generators (WTG) are addressed as the following: Foundation, Tower, Rotor, Nacelle, Drive train, Generator, Electrical system, Control system, Safety system and Hydraulic system (Van Hulle et al, 2001, pp.1-45; Wizelius, 2007, pp.1-304; Cantú, 2011, pp.73; Puglia, 2013, pp.1-73).

3.2.3.1. Small Wind Turbines

Small wind turbines is a turbines with a diameter of less than 15m and a power output below 50kW. However, most small wind turbines have a diameter of around 7m or less and a power output ranging between 1kW and 10kW. For very small installations, such as a remote household, wind turbines can have a diameter smaller than 2m and an output of 1kW or less. Medium size wind turbines have a rotor diameter of 15-30m, and a maximum output of 50-250kW (Rolland & Auzane, 2012, pp.12).

The majority of small-scale wind turbines are built on freestanding poles or towers. Such turbines are directly installed on a building, usually on the rooftop. Both vertical and horizontal axis turbines can be building-mounted, but they might be subject to more turbulence. The tilt-up poles/towers are very popular in developing countries since they are easy to install and offer good accessibility for maintenance and repair (Rolland & Auzane, 2012, pp.12).

Most small wind turbines have a permanent magnet generator and do not require a gearbox. This type of generator produces alternating current (AC), which must be rectified to direct current (DC)) the DC-voltage allows the use of these turbines for battery charging. For charging systems, a charge controller is added to prevent the battery from overcharging. In grid-connected systems, an inverter is used to control the SMWT and for supplying electricity to grid voltage and grid frequency. A dump load is required to protect the inverter from overvoltage and to prevent the turbine from over speeding (Rolland & Auzane, 2012, pp.12).

3.2.4. Biomass Energy

Biomass is a renewable, available and economic resource of energy that has potential to substitute fossil fuels in many applications such as heat, electricity and biofuels (Balaman and Selim, 2016, pp.863–885). The increased use of the agricultural biomass can help the agricultural based societies in achieving energy security and creating employment without causing environmental degradation. But, the viability and feasibility of electricity generation from

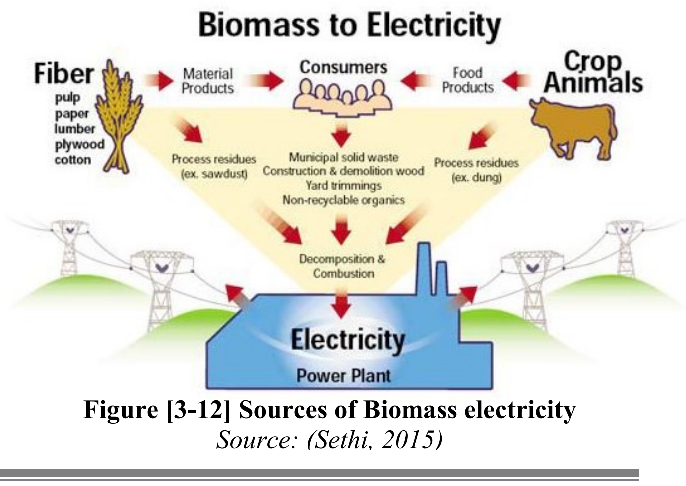


Figure [3-12] Sources of Biomass electricity
Source: (Sethi, 2015)

agricultural biomass depends upon the availability of biomass supply at a competitive cost (Singh, 2015, pp.286–297).

Direct heating is the most widespread application, but electricity production is gaining considerable interest among energy policy makers (Kapur, Kandpal and Garg, 1998, pp.573–583; Somashekhar, Dasappa & Ravindranath, 2000, pp.55–63; Purohit, 2009, pp.181–193; Krukanont & Prasertsanb, 2004, pp.47–59; Upadhyay, et al, 2005, pp.7–43; Singh, 2015, pp.286–297). The major problem in the biomass power generation is availability of crop residues, which varies on regional basis due to its competitive uses and agricultural practices used in a region (Singh, 2015, pp.286–297; Balaman and Selim, 2016, pp.863–885).

The conversion technologies for utilizing biomass can be separated into four basic categories: direct combustion processes, thermochemical processes, biochemical processes and agrochemical processes (Singh, 2015, pp.286–297; Dagnall, Hill & Pegg, 2000, pp.225–234; Demirbas, 2001, pp.1357–1378; Van den Broek, Faaij & Van Wijk, 1996, pp.271–81).

Biomass (plant material and animal waste) is the oldest source of renewable energy, used since our ancestors learned the secret of fire as show in figure [3-12].

Biomass is a fancy name for material from plants and animals. Some kinds of biomass can be burned to produce energy such as wood. Plants absorb energy from the sun through the process of photosynthesis. When biomass is burned, this stored energy is released as heat. Burning biomass releases carbon dioxide. However, plants also take carbon dioxide out of the atmosphere and use it to grow their leaves, flowers, branches, and stems. That same carbon dioxide is returned to the air when the plants are burned (Sethi, 2015).

Many different kinds of biomass, such as wood chips, corn, and some types of garbage, are used to produce electricity. Some types of biomass can be converted into liquid fuels called biofuels that can power cars, trucks, and tractors. Leftover food products like vegetable oils and animal fats can create biodiesel, while corn, sugarcane, and other plants can be fermented to produce ethanol.

Until recently, biomass energy supplied far more renewable electricity or “bio-power” than wind and solar power combined, biomass can and should supply a huge amounts of bio-power. Sustainable, low-carbon biomass can provide a significant fraction of the new renewable energy we need to reduce our emissions of heat-trapping gases like carbon dioxide. Without sustainable, low-carbon bio-power, it will likely be more expensive and take longer to transform to a clean energy economy (Sethi, 2015).

Small-scale biomass heating and cogeneration plants may be a legitimate advance toward a renewable energy economy, large-scale biomass electricity presents the Faustian choice of burning the forest to keep the lights on. Electricity from biomass is increasingly promoted as a “green” alternative to fossil fuels. As in a coal- or natural gas-burning power plant, biomass fuels are burned to make steam, which drives a turbine to generate electricity. Although biomass can refer to many different potential fuels including crop residue, construction waste, and garbage, the majority of existing biomass fueled power plants burn wood. Wood has a much lower energy density than fossil fuels, which means that the mass of raw material input per electrical energy output is much higher for biomass than for either coal or natural gas. Industrial biomass energy production, particularly whole-tree harvesting for wood chip–burning power plants, is a growing threat to forest ecosystems. Biomass burning also produces dangerous air pollution, which is why many physician and medical groups are opposing biomass energy projects. Although biomass energy in theory has no net contribution to global greenhouse gas emissions because the carbon dioxide released during combustion will be recaptured by future forest growth (some question this assumption because climate change may reduce overall forest cover), there is a timing issue that is often overlooked by biomass proponents. The important time horizon for greenhouse gas reductions is the next fifty years. While CO_2 emitted by burning wood will eventually be sequestered, full recovery can be on the order of several centuries. Thus burning wood today may exacerbate global warming in the near term, especially since more wood must be burned compared to other fuels to get the same amount of energy (Butler, Lerch and Wuerthner, 2012, pp. 1-384).

3.2.5. Hydroelectric Power

Hydroelectric energy is the primary energy sources in the history of mankind (Mao et al, 2017, pp.2446–2453). Water is such a natural substance that cannot be substituted by any material and the mankind are dependent on it. But, as a result of rapid growth of population, the expansion of irrigated agriculture, economic development and industry, water resources are being stressed both quantitatively and qualitatively. Water power resources are the basis for sustained renewable electricity generation (Capik, Yılmaz and Cavusoglu, 2012, pp.6160–6172; Akpınar, 2013, pp.206-219).

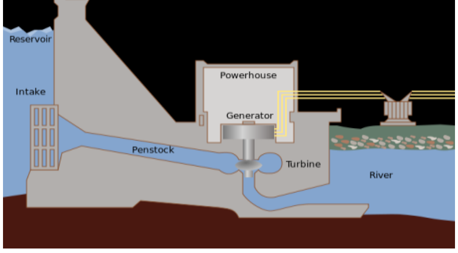


Figure [3-13]: Details of hydroelectric dams

Among all renewable sources, hydropower is a clean and common source, providing about 88% of the world's electric power (Nautiyal, Singal & Sharma, 2011, pp.2021–2027). It has remained by far the most important renewable source for electrical in the world (Kaygusuz, 2004, pp.215-224; Bakıs, 2007, pp. 259–66; Ozturk, Bezir & Ozek, 2009, pp.605-615; Akpınar, Kömürcü & Kankal, 2011, pp.1201-1209; Akpınar, 2013, pp.206-219).

Types of Hydropower

- Conventional hydroelectric, referring to hydroelectric dams as shown in figure [3-13].
- Micro hydro projects which provide a few kilowatts to a few hundred kilowatts to isolated homes, villages, or small industries dams as shown in figure [3-14].

Figure [3-14]: Micro hydro in Northwest Vietnam

- Small hydro projects are 10 megawatts or less and often have no artificial reservoirs as shown in figure [3-15].
- Run-of-the-river hydroelectricity, which captures the kinetic energy in rivers or streams, without a large reservoir and sometimes without the use of dams as shown in figure [3-16].

Figure [3-15]: Small hydro stations in Shennongjia,

- Conduit hydroelectricity projects utilize water which has already been diverted for use elsewhere; in a municipal water system, for example.
- Pumped-storage hydroelectricity stores water pumped uphill into reservoirs during periods of low demand to be released for generation when demand is high or system generation is low as shown in figure [3-17].

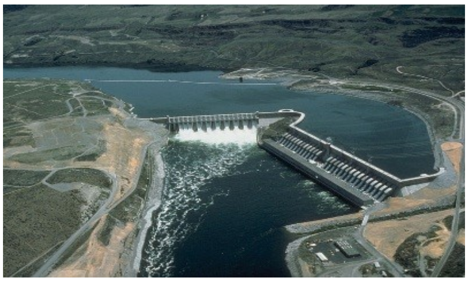


Figure [3-16]: The run-of-the-river station in Chief Joseph Dam

Figure [3-17]: Pumped-storage hydroelectricity

Ancient societies used watermills for grinding grain and other mechanical needs. Hydropower is now the largest and lowest-cost source of renewable energy in the world. But it does have serious ecological impacts it effectively kills wild rivers (Kaygusuz, 1999, pp.275–290; Akpınar, 2013, pp.206-219). Damming a river can completely alter the natural ecosystem by flooding the upstream portion and altering flow rates and natural silt deposition downstream. The resulting habitat fragmentation, loss of water quality, and changes in species diversity may put increased pressure on vulnerable species. The future growth potential of hydropower in most developed countries is limited. More than 45,000 large dams already degrade rivers across the Earth. Small-scale hydropower "micro-hydro" and called "run of the river" technologies that generate power without dams or impoundments can be ecologically benign and a useful part of regional distributed energy efforts; their total potential generating capacity, however, is modest. Other emerging hydropower technologies, including tidal and wave power, have not yet proven commercially viable and in terms of cost and power generation when compared to traditional hydropower (Altinbilek, 2002, pp.61-65; Bakıs, 2005, pp.495–516; Berkun, 2010, pp.648–58; Akpınar, Kömürcü, Özölçer & Senol, 2011, pp.252–262; Dursun & Gokcol, 2011, pp.1227–1235; Erdogdu, 2011, pp.689-696; Uzlu, Akpınar & Kömürcü, 2011, pp.676–688; Butler, Lerch & Wuerthner, 2012, pp. 384).

Hydro-turbines convert water pressure into mechanical shaft power, which can be used to drive an electricity generator, or other machinery. The power available is proportional to the product of pressure head and water discharge. Hydropower continues to be the most efficient way to generate electricity (Binder, 2000, pp.15; Kaygusuz, 2004, pp.215-224; Muneer, Maubleu & Asif, 2006, pp.1–23; Panwara, Kaushikb & Kotharia, 2011, pp.1513–1524; Capik, Yılmaz and Cavusoglu, 2012, pp.6160–6172) Multiple small-scale hydropower systems have low negative effects on nature and human beings (Edinger & Kaul, 2000, pp.295–313; Ozturk, Bezir & Ozek, 2009, pp.605-615; Capik, Yılmaz and Cavusoglu, 2012, pp.6160–6172; Mao et al, 2017, pp.2446–2453).

3.2.6. <u>Geothermal</u>

Geothermal energy is the energy stored in the form of heat beneath the earth's surface. Our planet is a huge source of energy, 99.9 % of the planet is at a temperature greater than 100°C; so geothermal energy is a significant renewable resource. Geothermal energy is a carbon free, renewable and sustainable form of energy that provides a continuous, uninterrupted supply of heat and can be used to heat buildings and generate electricity as shown in figure [3-18].

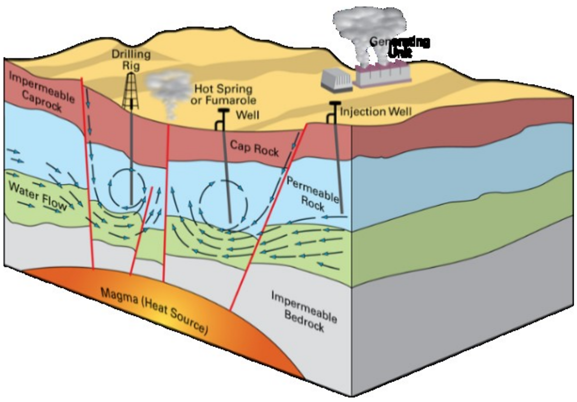


Figure [3-18]: Simplified diagram of a geothermal power plant
Source: (Geothermal energy, 2016)

In some places the natural groundwater, heated by this geothermal energy, finds its way to the surface and emerges in hot springs or steam geysers, which have been used by humans for bathing and agriculture since pre-history (Geothermal energy, 2016). Geothermal power offers both firm and flexible solutions to the changing the countries power system. It is well known that geothermal plants can operate 24 hours a day with a steady output, regardless the environmental conditions, and are not subject to the voltage swings. It can fulfill the necessary role of a renewable base-load power source (Matek & Schmidt, 2013, pp.19). Geothermal energy utilizes the heat produced by the Earth’s core to create electricity and to heat homes. Geothermal energy is naturally vented the Earth’s surface in the form of volcanoes, geysers, and hot springs. Large amounts of geothermal energy are vented at the intersections of tectonic plates as well. Geothermal energy can be used to produce electricity by either harnessing steam directly from geothermal resources or by using hot geothermal water to produce steam to run a turbine. Few countries produce a significant share of electricity from geothermal sources; since the footprint of a geothermal plant is fairly small, most of the environmental damage that comes from geothermal energy production is associated with the construction of the facility and its related transmission infrastructure. Geothermal energy is consistent, and thus is one of the only renewable energy technologies that substitutes well for coal generation. Geothermal energy may also be used to regulate temperature in buildings, providing an alternative to conventional heating and air conditioning. Hot water from a geothermal source can be pumped directly into buildings for heat. Alternatively, geothermal pumps can utilize the constant temperatures (between 50 and 60 degrees Fahrenheit) found only a few feet underground to cool buildings in the summer and heat them in the winter. The next generation of geothermal energy, "enhanced" geothermal, aims to harness underground heat sources that otherwise lack water or permeability but are broadly distributed geographically (Butler, Lerch & Wuerthner, 2012, pp. 384). Geothermal plants generally lack the fuel costs of other base-load sources, or the ancillary and transmission costs associated with variable energy resources that often equate to the long-term stability in energy costs (Matek & Schmidt, 2013, pp.19). Geothermal power has very low emission levels. Binary plants produce near-zero GHG emissions while flash and dry steam plants represent a significant reduction compared to fossil fuel based generation (Matek & Schmidt, 2013, pp.19).

3.3. STREETSCAPE

Since the 1500s streetscape design has evolved with the planning movements and city forms from the narrow winding roads of the organic city to the wide motorways of the modern era, streets continue to be a vital component in the physical design and social success of our communities (Frank, 2010, pp.1-167). Nowadays streetscape design is known to be the design of streets with its road beds, sidewalks, landscape planting, and the character of the adjacent Building façade or planted setbacks (Frederick, 2006, pp.1-448).

According to Laura Frank "Historically, streets have provided both a means of livelihood and social support for its inhabitants. The emergence of the car dramatically shifted planning practices from the pedestrian, to the efficient movement of automobiles, resulting in the fragmentation and dispersion of communities. Street design also has a direct influence on significant issues such as climate change, public health, social justice, upon human's lifestyles and behaviour's inclusivity and local and district economies. Designing Streets recognizes these pressures and seeks to build a collective response through the design of new streets and the regeneration of existing streets that is informed by as wide a range of issues and stakeholders as possible (Frederick, 2006, pp.1-448).

"Streetscapes describe the area where public and private interests combine to create the identity of a commercial district, they includes a variety of elements, such as vehicle travel and parking lanes, bike lanes, sidewalks and carriage walks street furniture, bus stops, utility poles, trees, accent plantings, and signage (Janet L. Attarian, 2003). All of these items occur in one of three major zones of the streetscape; The Sidewalk Zone, The Parking Zone and The Roadway Zone as shown in figure [3-19].

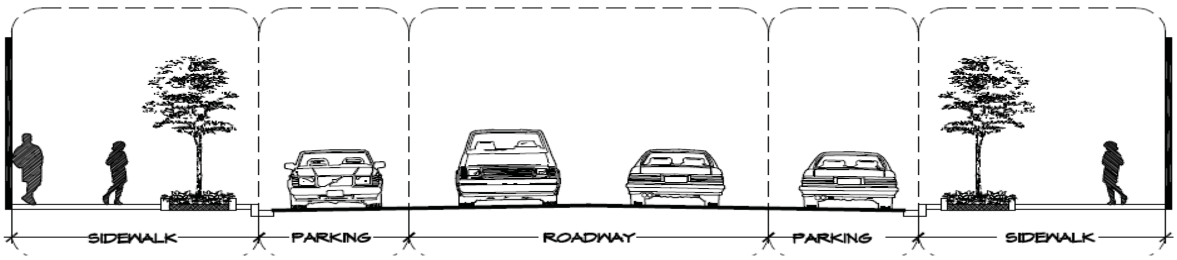


Figure [3-19] Street zones
Source: (Janet L. Attarian, 2003)

The Sidewalk Zone is the "front porch" of every business and residence, it is the place where people meet their neighbours, interact, or simply enjoy a stroll. It allows pedestrians access throughout the streetscape into residences and businesses, it also might include Pedestrians traverse zone for the people coming from their cars, accessing shops and residences, or simply walking through the commercial district. The second zone, which is called the "Parking Zone" allows the shoppers who travels by car to patronize a commercial district. It is also the location of loading zones for businesses as well as transit stops. The third and final zone is the “Roadway Zone”, or it could be called the vehicular zone that generally allows the movement of motor vehicles through a streetscape, it may also provide a lanes for bicycle traffic adjacent to the parking zone. Underground utilities are often located in this zone, although it is hidden beneath the zone (Janet L. Attarian, 2003).

The streetscape features are set according to the type of streets, each street has a different purpose and different conditions such as; Freeways, Highways, Primary roads, Secondary roads, Service roads, pedestrian walks. The “Freeways” consists of 1 or 2 lanes, no speed limits, no stops, no cross traffic, no speed limits but it might has a minimum speed limits. Highways that are used to connect the cities, they have high speed limits, multi lanes, no cross traffic, contain service roads, & turning traffic is minimized, specified to specific lanes, & are elevated on a higher level. Primary roads that are used to connect districts, they have multi lanes with maximum speed limits, lots of returning traffic, bicycle lane, and service roads. Secondary roads that are used to connect the main roads and its main purpose is to access the buildings, they have 1 or 2 lanes and used to gives addresses. Service roads that are used in the highways and primary roads, they are 1 lane that is used for entering parking, shopping zones, and building to avoid causing traffic jam and accidents. And finally the pedestrian walks that are used in the shopping areas and around the primary roads to separate the walking people from the vehicle areas.

3.3.1. STREETSCAPE ELEMENTS

Streetscape elements are placed in public or communal area to maintain decorative and functional aspects (City of Tshwane, 2007, pp.1-75). Many streetscape designers, architects and urban designers considered streetscape elements as aesthetic, healthy and point of attraction in their designs and that was a result of what the researchers achieved through their research path while trying to understand the amazing effect of streetscape elements on human health, social life, spirit, economic, environment and psychology of human actions. This helped the people to think more about the importance of streetscape elements. Many researchers classified the streetscape elements differently through time as shown below in table [3-1].

TABLE [3-1] Different Classification for Landscape Elements

Source	Streetscape Elements
(Streetscape elements, 2001)	(I) Street Paving (2) Sidewalks (3) Curbs & Curb Ramps (4)Street Lighting (5) Seating, Benches & Bus Shelters (6) Fountains (7) Public Art (8) Kiosks (9) Tree Grates (I0) Planting Pots & Planters (I1) Trash Receptacles (I2) Bicycle Racks (I3) Bollards (I4) Utility Accessories (I5) Newspaper Racks
(Fukahorin & Kubota, 2003, pp.75–91)	(I) Road paving, (2) Street furniture, (3) Vegetation (4) Roadside buildings
(Daley, 2003, pp.1-129)	(1) Lighting (2) Trees and Plantings (3) Sidewalk Pavement (4) Roadway Pavement (5) Street Furniture (6) Community Identifiers (7) Parking (8) Traffic Control Devices (9) Signage
(City of Milwaukee, 2011, pp.1-96)	(1) Lighting (2) Tree and Plant Materials (3) Planters (4) Sidewalk Pavement (5) Street Furniture
(Rehan, 2013, pp.173-186)	(1) Sidewalks, (2) Street corners (3) Trees and landscape strips(4) Rain garden (5) Planters (6) Street furnishing (7) Benches (8) Lighting (9) Trash receptacles (10) Signage (11) Bus shelter (12) Medians (13) Curbs (14) Bicycle facilities (15) Crossing (16) Public art (17) Cafe spaces
(City of Cheyenne, 2017, pp.1-33)	(1) Sidewalks (2) Street Corners and Curb Extension (3) Trees and Landscape Strips (4) Planters (5) Seating (6) Trash/Ash Receptacles (7) Public Art (8) Screening (9) Fences, Railings, and Walls (10) Cafe Spaces (11) Special Event Spaces (12) Alley and In-Fill Spaces (13) Fixtures/Utility Zone (14) Utilities (15) Lighting
(City of Toronto, 2017)	(I) Paving (2) Street Trees (3) Medians, (4) Lighting (5) Street Furniture (Seating, Benches & Bus Shelters)

The framework of streetscape elements used in this research was collected from the elements presented in Table [3-1]. This framework summarizing all the elements that has been described before in Table [3-1] by different researchers and these elements are (1) Paving (Crossing, Road paving, Sidewalks, Street corners, Parking, Curbs), (2) Vegetation (Trees, landscape strips, Planting Pots & Planters), (3) Street Squares (Medians), (4) Lighting, (5) Street Furniture (Trash receptacles, Seating, Benches, Bus Shelters, Signage, Newspaper Racks, Bicycle Racks, Traffic Control Devices, Telep. Booths) (6) Rain drainage, (7) Cafe Spaces, (8) Kiosks, (9) Fountains, (10) Fences, Railings, and Walls, (11) Public Art as shown in Figure [3-20].

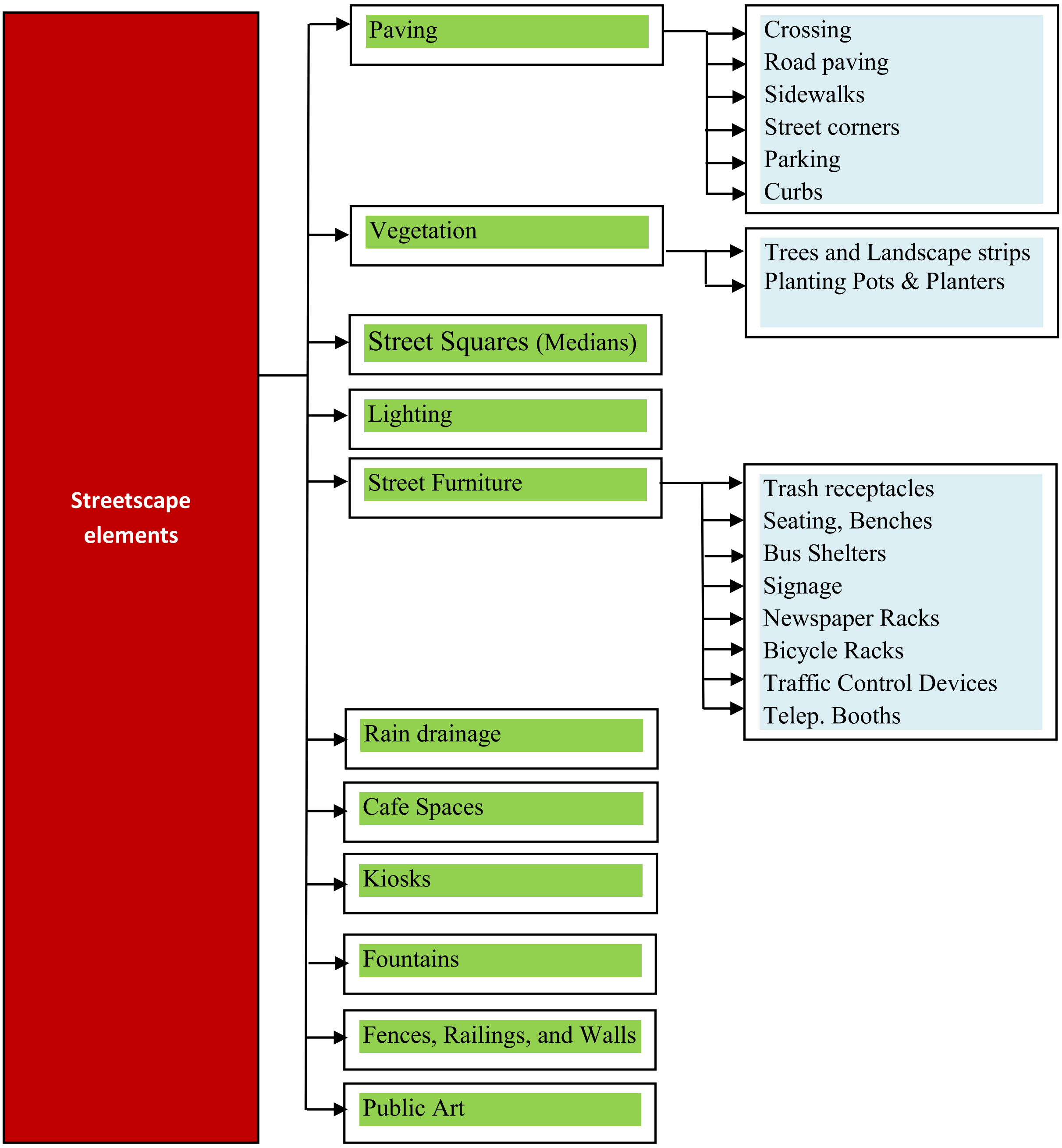


Figure [3-20]: Streetscape elements
Source: By researcher

3.3.1.1. <u>Paving</u>

The Paving section consist of crossing, Road paving, sidewalks, street corners, parking and curbs. This section will identify and describes the differences between these elements as well as the material used in constructing these elements.

A. Crossing

Crosswalks are where pedestrians allowed to cross City streets, and they are considered as a part of the pedestrian's network. Crosswalks should be made of special paving as shown in figure [3-21] (Rehan, 2012, pp.173-186). The Guide for the Planning, Design and Operation of Pedestrian Facilities defined the Crosswalks as "the extension of a sidewalk or shoulder across an intersection, whether marked or not".

Figure [3-21]: Crosswalks
Sources: (Streetscape elements, 2001)

Crosswalks generally consist of two parallel lines perpendicular to the direction of traffic, they are vary in width (6'-10') and should be align to the edge of the right side. Typically they are set back to back of the curb. (Daley, 2003, pp.1-129). Enhancing the crosswalk paving can make motorists more aware of pedestrian activities. Moreover, enhancing the crosswalks pavements will designate a safe pedestrian circulation'' (EIP Associates, 2006, pp.152–157; RRM, 2007, pp.61–63.; Rehan, 2012, pp.173-186).

B. Road paving

Pavement is an essential component of any streetscape, it forms the floor of the outdoor environment in which people live, work, and play every day. The pavements is one of the most important elements for setting the human perspective and mood toward the space. (Daley, 2003, pp.1-129; Rehan, 2012, pp.173-186). Road Paving is a vehicle areas, in most cases it is made of asphalt, but in areas like town plaza it is preferred to be made of coloured concrete or coloured bricks (Streetscape elements, 2001).

Figure [3-22]: Street paving
Source: (Streetscape elements, 2001

C. Sidewalks

Sidewalks are the pavements in front of the buildings; Sidewalks provide safe, attractive, interesting and comfortable spaces for pedestrians by providing well designed and coordinated tree planting, lighting and street furnishings as shown in figure [3-32] (Toronto City Planning, 2006, pp.2–28). To achieve sustainable streetscape paving materials should be selected for reflectivity, green manufacturing, local sourcing and

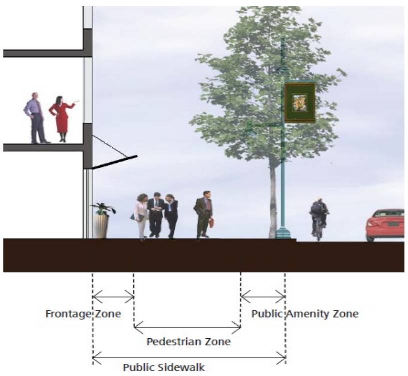


Figure [3-23]: Street's side walks
Source: Shellmound Streetscape Design Guidelines, 2012

permeability (Carrville District, 2004, p.87). It is preferred to be made of coloured concrete (Rehan, 2012, pp.173-186; Streetscape elements, 2001). Sidewalk width sets the stage for the streetscape, as it is the location in which the elements reside. Narrow spaces have greater limitations on the scale and size of elements that can be placed within the streetscape, while wider sidewalks offer more options. There are a variety of sidewalk widths on the streets, each one has its own design and opportunities (Daley, 2003, pp.1-129).

D. Street corners

Street corners increased the pedestrian spaces and it provides an opportunity for social interaction through the site furnishings and the placements of benches. Moreover it provides a safe refuge before crossing the streets. In addition to that, Street corners also provide shorter crossing distances for pedestrians as shown in Fig. [3-24] (Otak Inc. 2007, pp.2–14; Rehan, 2012, pp.173-186). Street corners is an important element for pedestrians, and in order to highlight these areas, streetscape finishes are upgraded at the corners, including the use of special pavements, lighting, seating, etc.

During designing Street corners, the streetscape designer must consider the wrap of the corners of the streetscape, as well as the length of the streetscape extended down side the streets (Daley, 2003, pp.1-129). Streetscape finishes can be extend to the building corners, window corners, other logical building breaks, or alleys, In order to blends streetscape within the context of the neighbourhood and immediate surroundings (Daley, 2003, pp.1-129).

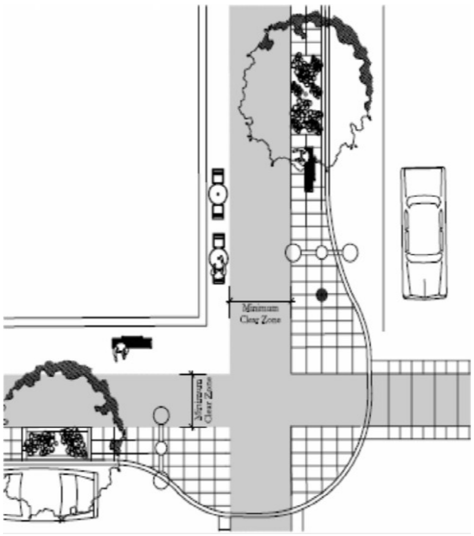


Figure [3-24]: Street corners
Sources: (City of Tshwane, 2007)

E. Parking

Parking is an important street feature, it contributes significantly to the safety and attractiveness of the streets. The Parking Zone allows shoppers who are travelling by car to patronize a commercial district. It is also the location of loading zones for businesses as well as transit stops design. Lay-by parking can increase the local economic activity by providing an easy access to the local services. Moreover, it makes the areas more vibrant and attractive to the consumers (Daley, 2003, pp.1-129). Lay-by

Figure [3-25]: Parking lains
Source: (Streetscape elements, 2001)

parking provides a shared space, reducing speeds and providing a safer and more appropriate pedestrian realm as shown in figure [3-25]. Parking lay-by should be delineated with different paving pattern and colours from road zones or travel lanes. Any section of lay-by lane must commence and end with a taper not less than 6m in length (Streetscape elements, 2001; Daley, 2003, pp.1-129). During the design process of streetscape, designing parking spaces are a premium for the community requests. A diagonal parking may be added to side streets between the arterial street and the alley. In order for diagonal parking to be constructed, all designs must be reviewed and several criteria's must be taken into consideration, which includes: Width of the right-of-way; Traffic direction on the street; Presence of utilities or mature trees; and the Adjacent land uses (Daley, 2003, pp.1-129).

F. Curbs

Curbs are defined as the edge that links between the street and the sidewalk. They acts as a sidewalk barrier, they prevents the vehicles from riding up onto the sidewalk. Moreover, Curb ramps provide a ramp that connect the sidewalks with streets for the disables with wheelchairs, pushing strollers, children on bicycles, and delivery services as shown in figure [3-26]. Curb ramps are required at all intersections and crosswalks, including mid-block crossings. Curbs must be located in each crosswalk and be made from the same materials as the sidewalks (Streetscape elements, 2001; Richard, 2003, pp. 3–17; Rehan, 2012, pp.173-186).

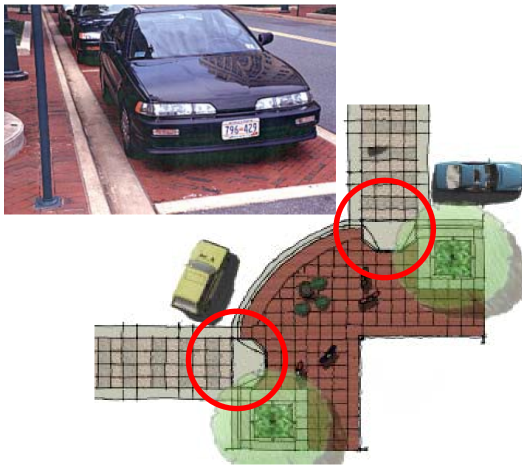


Figure [3-26]: Curbs at corners
Source: Streetscape elements (2001)

3.3.1.2. Vegetation

The vegetation is an important streetscape element. It is known with it environmental and aesthetic benefits in any urban context. Streetscape vegetation elements is divided into two elements; the trees and landscape strips and Planting Pots & Planters , they are mainly located between the sidewalks and the streets or between two streets or on walkways, building entrances, at seating areas etc.

A. Trees and Landscape strips

Trees and landscape strips are located between sidewalks and streets as shown in figure [3-27], it is an effective element that creates a buffer from moving vehicles and street noise. Moreover, it gives the sense of safety and it helps the pedestrians to feel more comfortable walking along the street. Sustainable streetscape are established through rain garden (Streetscape elements, 2001; Otak Inc. 2007, pp.2–14; Rehan, 2012, pp.173-186). Trees and landscape strips is limited; in narrow sidewalks, trees and landscape strips can be placed adjacent to the curb. In wider sidewalks, the installation of trees and landscape strips has a band of sidewalk (typically 1’-3’ wide, depending on the width of the sidewalk) between the curb and the tree and landscape strips. This creates an extra setback for the trees that minimizes conflicts with parked cars (Daley, 2003, pp.1-129).

Figure [3-27]: Trees and landscape strips in streets
Souce: (Shellmound Streetscape Design Guidelines. 2012)

B. Planting Pots & Planters

Planters are located on walkways, building entrances, at seating areas, and at the edges of parking lots, their purpose is to define or separate spaces and increase the aesthetics of a space. Planter should not block the pedestrian walks, and when added to street corners it must not block the drivers view (Rehan, 2012, pp.173-186; Streetscape elements, 2001). Planters add colour, texture and interest to a streetscape and can help define and separate spaces. They help define primary building entrances, and enhance aesthetic value. Planters placed on walkways should not create congestion or block pedestrian traffic, and placement on street corners should not obstruct driver’s view. They can be installed at seating areas, along the edges of parking lots, in pedestrian plazas, and in clustered furnishing areas. Storm water planters also play an important role in sustainable urban design by minimizing storm water runoff, reducing water pollution, and creating a greener and healthier appearance of the built environment by providing space for plants and trees near buildings and along streets (Otak Inc. 2007, pp.2–14; Tetra, 2009, pp.3–25; Rehan, 2012, pp.173-186). Planters should be placed a min. of 2.5cm from the back of the curb and have a minimum inside width of 10cm. Curbs form the edge of the planters and should be 15-20 cm wide (Daley, 2003, pp.1-129).

Figure [3-28]: street planters
Source: Streetscape elements (2001)

3.3.1.3. Street Squares (Medians)

Street Squares in some countries are called Medians. Street Squares or Medians are an effective method of making a streetscape more pedestrian friendly. Street Squares or Medians provide an efficient place for rain gardens. Street Squares or Medians gives the place a unique character and it has 3 primary purposes; it separate opposing traffic, it provide space for planting, and it provide a refuge for pedestrians during crossing the roads. Street Squares or Medians achieve sustainable streetscape through establishing a rain garden in green area, using sustainable materials in pavement, or using solar street lights (Alliance Downtown, 2006, pp.97–98; EIP Associates, 2006, pp.152–157; Rehan, 2012, pp.173-186; City of Toronto, 2017).

Figure [3-29]: Medians
Source: (Barcelona City Center Traffic Scene, 2017)

3.3.1.4. Lighting

Lighting is an important element in streetscape. Lighting features are adjacent to the sidewalks, walkways and bike lanes, it is placed in the sidewalk and aligned at an equal spacing from the sidewalk edge. Its main purpose is to maintain a safe environment by increasing the safe and security of the street. Moreover, it creates an aesthetically pleasing public spaces and comfort pedestrians. Since that the lighting feature are large, highly visible transclosures and they are a significant elements in the streetscape, lighting feature should be given a graphic design for community-oriented image as shown in figure [3-30]. All lighting fixtures should be energy efficient and provide minimal light emissions to prevent night sky pollution (Streetscape elements, 2001; Rehan, 2012, pp.173-186; City of Tshwane, 2015, pp.10–11; Otak, 2017, pp.1-33; City of Toronto, 2017).

Figure [3-30]: Street lighting
Source: Streetscape elements (2001)

3.3.1.5. Street Furniture

A. Trash receptacles

Trash receptacles may be the most used streetscape elements, Trash receptacles are often located near seating areas, pedestrian walks, corners, benches, and bus

Figure [3-31]: Trash receptacles
Source: (Streetscape elements, 2001)

stops. Trash receptacles play a very important role in maintaining a clean healthy environment. Materials used for trash receptacles should be sustainable, or recycled materials to achieve sustainability in streetscape as shown in figure [3-31] (Streetscape elements, 2001; Rehan, 2012, pp.173-186). Waste receptacles are usually placed two per block, on opposite corners at intersections or one minimum trash receptacle should be placed at every corner. The local community generally verifies actual locations during the design phase of the project (Streetscape elements, 2001; Daley, 2003, pp.1-129; Otak Inc. 2007, pp.2–14; Rehan, 2012, pp.173-186).

B. Seating, Benches

Seating benches are located in streets corners, main pedestrian’s nodes, or gathering places, they are used in waiting areas, outdoors cafes, and bus shelters. Benches contribute in making the cities an enjoyable space for pedestrians. The purpose of seating is for waiting and resting in areas along walkways. It provide a place to interact and observe. Seating on street corners must not obstruct driver’s views as shown in figure [3-32] (Otak Inc. 2007, pp.2–14). Benches are usually placed at bus stops, mid-block, corner intersections, or other locations within the streetscape where people tend to gather. The local community generally verifies actual locations during the design phase (Daley, 2003, pp.1-129; Richard, 2003, pp. 3–17). It is preferred to be made of sustainable materials or recycled materials in order to achieve economic efficiency and sustainable streetscape (Rehan, 2012, pp.173-186; Streetscape elements, 2001).

Figure [3-32]: Street benches
Source: Streetscape elements (2001)

C. Bus Shelters

Bus shelters protects the passengers from weather using a light structures located at bus stops as shown in figure [3-33]. All bus shelters should have a bus stop signs and should be provided with benches and trash receptacle. The sustainable approach of bus shelters is installing green roofs to each bus shelter to have a larger effect on environmental quality. Moreover, bus shelters could be constructed using recycled materials (Cotellessa, et al, 2010, p.39; Rehan, 2012, pp.173-186).

Figure [3-33]: Bus Shelters
Source: Archi expo (2017)

D. Signage

Streets signage are usually located on the streets sidewalks and they must be visually clear for drivers and pedestrians to sever its main purpose which is maintaining a visual street guide that spreads streets information effectively as shown in figure [3-34] (Streetscape elements, 2001; Los Angeles design guidelines, 2002, p.100). The signage style should be clear, timeless and flexible. Solar signage are used in streets as a sustainable streetscape elements that has long lifetime, (Albiba, 2019). Another benefit or street signage which is raising the awareness toward environmental benefits. Signage system should be designed to utilize environmentally friendly materials and simple construction methods (Streetscape elements, 2001; Los Angeles design guidelines, 2002, p.100; Cotellessa, et al, 2010, p.39; Rehan, 2012, pp.173-186).

Figure [3-34]: Street signage
Source: Streetscape elements (2001)

E. Newspaper Racks

Newspaper racks should be designed to be blend with the surroundings and grouped together to provide a service to the public as shown in figure [3-35]. It should be located at pedestrian nodes or gathering places and should be placed appropriately to serve the public properly, Should not obstruct any signs or views for vehicles and pedestrians, in addition to that it should not obstruct the displays of businesses shops or cafes. (Streetscape elements 2001).

Figure [3-35]: Newspaper Racks
Source: Streetscape elements (2001)

F. Bicycle Racks

Designing sustainable streets should include bicycles lanes. Bike lanes should be located in commercial districts near critical masses of retail shopping or between the sidewalks and the parking lane, they have a very important role in decreasing the traffic congestions. There also must be bike racks to help the residents in parking their bikes safely and to insure that the bike is secure as shown in figure [3-36] (Streetscape elements, 2001; Daley, 2003, pp.1-129; Rehan, 2012, pp.173-186).

Figure [3-36]: Bike racks
Source: Streetscape elements (2001)

Bicycle facilities can be determined as follows: Bike lanes which can achieve a streetscape experience between the sidewalks and parking lane. The impact of a bike lane on a neighbourhood may be to reduce traffic congestion and pollution (Richard, 2003, pp. 3–17; Rehan, 2012, p.173-186). Bicycle racks are important amenities that will encourage bicycle riders and promote alternative modes of transportation. Bike racks should be installed at convenient locations along streets, typically near building entries (RRM, 2007, p.61–63; Rehan, 2012, p.173-186).

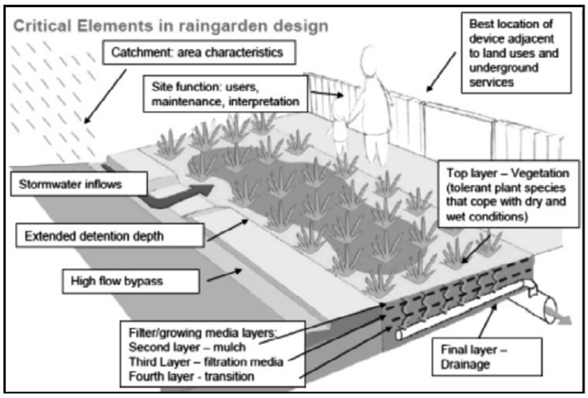
G. Traffic Control Devices

Traffic control devices shall be defined as all signs, signals, markings, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, pedestrian facility, or bikeway by authority of a public agency having jurisdiction as shown in figure [3-37]. Traffic control device is used to organize the traffic density (Daley, 2003, pp.1-129; MUTCD, 2019)

Figure [3-37]: Traffic control devices, signage, and identifiers on Howard Street
Source: (Daley, 2003)

3.3.1.6. Rain drainage

Rain drainage is used to treat storm water. When rain water falls in garden it is passed through a natural filter which is planted and vegetation. After that, treated storm water is fed back into the drainage system or left to infiltrate into the underground. Rain drainage can provide a greener solution to treating storm water and reduce the demand on potable water to water the plants as shown in figure [3-38] (Jennings, 2012, p.1; Rehan, 2012, pp.173-186).



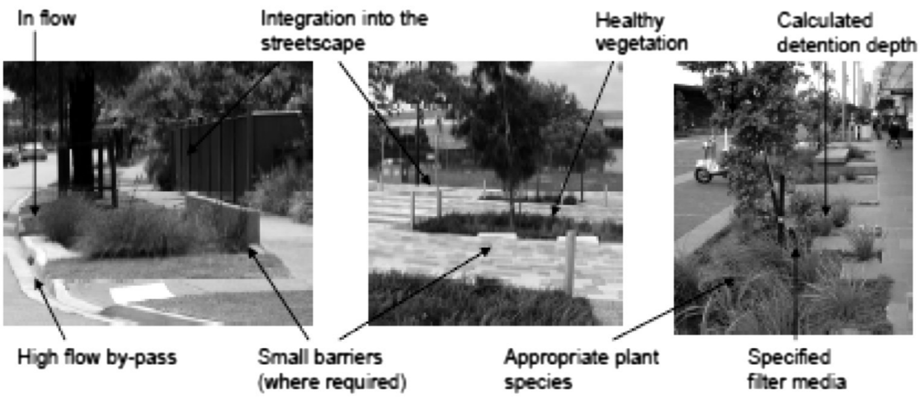


Figure [3-38]: Sustainable rain drainage.
Source: Rehan (2012)

3.3.1.7. Café spaces

Outdoor cafés provide an active street and natural locations for spontaneous social interactions as shown in figure [3-39]. Corner cafe´s are usually placed against the building edge, rather than at the outer edge of the sidewalk, to maintain visibility at intersections (Otak Inc. 2007, pp.2–14; Rehan, 2012, pp.173-186; City of Cheyenne, 2017, pp.1-33).

Figure [3-39]: Outdoor café space

3.3.1.8. Kiosks

Kiosks are usually used for retail purpose or to impart community information to the public. It should respect the street furniture such as benches and lighting. The design of the kiosk should be accessible and attractive from all sides and it should be well-illuminated as shown in figure [3-40]. The fixed kiosks should give the sense of permanence with other fixed surroundings. Kiosks can be mobile to allow the flexibility in public areas (Streetscape elements 2001).

Figure [3-40]: Streetscape kiosks
Source: Streetscape elements (2001)

3.3.1.9. Fountains

Fountains are always located in city squares or street corners, its purpose is to emphasise a specific area, attract the passenger attention, and encourage sitting on its edges and encourage spontaneous social interactions as shown in figure [3-41] (Rehan, 2012, pp.173-186; Streetscape elements, 2001).

Figure [3-41]: Streets fountains
Source: Streetscape elements (2001)

3.3.1.10. Fences, Railing and walls

Fences, railing and walls, provides a visual buffer between pedestrian and vehicular spaces and it could be considered as a continuation of the street wall. Delineation between the two can also improve public safety through separation of public areas from parking and circulation areas, as well as grade changes (City of Cheyenne, 2017, pp.1-33).

3.3.1.11. Public art

Public art helps to identify the identity of the space; it should be accessible physically and intellectually. It could include water features, seating, planting, decorative elements. Public arts must be made of durable materials as shown in figure [3-42] (Streetscape elements, 2001).

Figure [3-42]: Public arts
Source: Streetscape elements (2001)

Public art can help establish a unique identity, enhance civic pride, depict a cultural or historic event, and add interest to public spaces (City of Cheyenne, 2017, pp.1-33).

Public art can become a local landmark, or simply add richness to a building or landscape. Public art can tell complex stories about communities and their histories. These reinforce community identity, and provide a basis for community pride and ownership (EIP Associates, 2006, pp.152–157). One of the ways to expand the opportunity for art is to take it beyond the decorative elements to the functional elements. Streetscape elements, such as light poles, manhole covers, sidewalks, tree grates, tree guards and street furniture are all suitable elements for artistic expression (Daley, 2003, pp.1-129; Alliance Downtown, 2006, pp.97–98; Rehan, 2012, pp.173-186).

3.4. SUMMARY

This chapter summarizing the advantage and disadvantage of the main six renewable energy (RE) sources which are solar energy, Piezoelectric cells, wind turbines, Biomass energy, hydropower energy and geothermal energy. The chapter presents the different materials used in constructing these devices and the different techniques used to generate from this sources and finally the impact of this sources on greenhouse gases (GHG) production and reduction.

In addition, this chapter also presents a framework for streetscape elements consist of 11 elements and it identify the properties of these elements and the differences between them. This chapter is a literature review chapter and it has been presented to prepare the readers for the next Empirical chapters and to give them a full understanding toward RE sources and streetscape elements before they read the relationship matrix in the next chapter “chapter four”.

CHAPTER FOUR

EMPERICAL SECTION

4.1 INTRODUCTION

The aims of this research is to reduce the roads carbon emission using Smart-Streetscape elements (SSSE) which occurs from integrating streetscape elements with renewable energy generation devices.

This chapter will identify new tools to reach the aim of this research, by presenting new carbon statistical model to calculate the carbon emissions from roads without using heavy and expensive equipment's. In addition to that, the chapter will identify, analyse and present the properties of Smart-Streetscape elements which occurred from integrating streetscape elements with renewable energy (RE) sources as shown in figure [4-1].

The identification of Smart-Streetscape elements will take place in this chapter in four phases. Phase one: relation matrix, which identify the streetscape elements such as: Sidewalks, Trees and landscape strips, Street corners, Planters, Street paving, Benches, Lighting, Trash receptacles, Medians, Curbs, Bicycle facilities, Crossing, Public art, Signage, Rain garden and Fountains, that can be integrated with RE devices such as solar energy, wind energy, biomass, hydropower energy, piezoelectric energy and geothermal energy.

Phase two: Cross-sectional surveys, in which a data will be collect to identify the different properties of streetscape elements and RE devices. Phase three: Smart-Streetscape elements database, which presents the properties of Smart-Streetscape elements. Phase four: presents SSSE software. In this phase, the research presents a user-friendly software called "SSSE" software in which it presents the Smart-Streetscape elements database using online application to encourage the users (streetscape designers, architect, landscape architects, urban designers and transportation engineering's) to use Smart-Streetscape elements instead of regular streetscape elements without needing the consultancies of mechanical or electrical consultant as shown in figure [4-1].

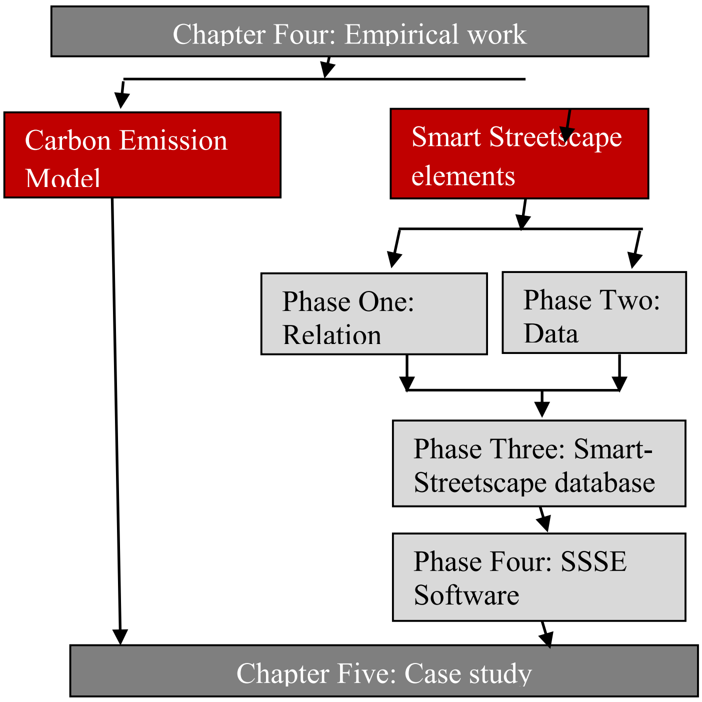


Figure [4-1]: Empirical framework

4.2 CARBON EMISSION MODEL

In order to calculate the carbon emissions in roads and streets. A heavy and expensive equipment's is required and it is only used in existing sites. In this section the research will present a new model for measuring CO_2 emission as result of electricity consumption and vehicles motion in highway roads that has length L Kilometers (km). This model can also estimate the average of CO_2 emission produced from a designed and under construction highway roads by considering two main variables such as the average traffic density and the amount of electricity consumed in the highway roads.

The highway roads carbon emissions is produces from the electricity consumed to power the roads and from the type and fuel used during vehicles motion. Therefore, CO_2 model is divided into two parts; the first is calculating the carbon emissions produced from electricity consumption and the second part is calculating the carbon emissions produced from vehicles motion.

In order to calculate the carbon emissions using this model, a site survey need to be done first to identify the following data; electricity consumption features, traffic density and types of vehicles.

4.2.1 CO_2 Emission from Electricity Consumption

On both sides of highway roads, there is some features that consume electricity such as a lighting features, traffic controlling devices, electronic signs and monitoring cameras. Each of which consumes electricity energy E kilowatt-hours (kWh). The energy E in (kWh) per day is equal to the power P in watts (W) times' number of usage hours per day t divided by 1000 watts per kilowatt:

$$E(kWh=day) = P(W) \ x \ t(h/day)/1000(W/kW):$$

The following table [4-1] represents the average grams of CO_2 emitted to produce one kWh of electricity and heat using various energy sources, the data vary depending on the performance of power plants.

Table [4-1]: CO_2 emitted against various energy sources.
Source: https://www.sunearthtools.com/tools/CO2-emissions-calculator.php#top

Fi	**Fuel**	**CO_2 g/kWh**
i=1	Other bituminous coal	840
i=2	Sub bituminous coal	930
i=3	Lignite brown coal	950
i=4	Patent fuel	860
i=5	Natural gas	380

For more details about emissions of CO_2 based on different energy sources, see, https://www.sunearthtools.com/tools/CO2-emissions-calculator.php#top. Then for any fuel source $F_i, i = 1,2,\ldots,5$, the CO_2 emission (CE) as result of usage electricity consuming features such as lighting features, traffic controlling devices, electronic signs and monitoring cameras in highway of length L is

$$CEe(A, E, Fi) = AEFi,$$

4.2.2 CO_2 Emission from Vehicles Motion

In this model, two types of vehicles are considered. The first type of vehicles moved by gasoline and is divided into $g_1, g_2, \ldots, g_n$ according to the type of vehicle such as Honda, Ford, etc. Each one of these types has fuel consumption rate $r_{g1}, r_{g2}, \ldots, r_{gn}$, (mile per gallon). The second type of vehicles moved by diesel and is also divided into $d_1, d_2, \ldots, d_m$ according to the type of vehicle, each one of these types has fuel consumption rate $r_{d1}, r_{d2}, \ldots, r_{dm}$, (mile per gallon). Then the CO_2 emission as a result of the motion of two types of vehicles (operating by gasoline (g) and diesel (d))

$$CE_{vm}(g,d) = L\left(\sum_{j=1}^{n}[No.of\ \ (g_j)] \times C(r_{g_j}) + \sum_{j=1}^{m}[No.of\ \ (d_j)] \times C(r_{d_j})\right),$$

in highway of length L is given by

Where $C(r_{gj})$ represent the grams of CO_2 per km as a result of fuel consumption rate r_{g1}(mile per gallon) and $C(r_{dj})$ represent the grams of CO_2 per km as a result of fuel consumption rate r_{dj} (mile per gallon). From Equations (2) and (3), the CO_2 emission (in gram) as a result of electricity consumption and vehicles motion through highway has length L is

$$CE = CE_e(A, E, F_i) + CE_{vm}(g, d)$$

$$= \quad AEF_i + L\left(\sum_{j=1}^{n}[No.of \quad (g_j)] \times C(r_{g_j}) + \sum_{j=1}^{m}[No.of \quad (d_j)] \times C(r_{d_j})\right), i = 1, 2, ..., 5. \qquad (4)$$

The two terms $C(r_{gj})$ and $C(r_{dj})$ can be computed using the following source [2], after knowing r_{gj} and r_{dj}, respectively. The values of r_{gj} and r_{dj} can be found in [3].

4.2.3 Example (Simulated data)

Data in this example is collected across four stages as following in Tables 2,3,4 and 5, through highway has length L = 10km: On other hand the number of light poels A = 4000; each of which has power P = 500W and the number of usage hours per day is t = 12h: If the energy source is Natural gas, then F_5 = 380g/kWh emitted carbon. Using Equation (1) and (2), then

Table [4-2]: CO_2 emission from 12 am. to 6am. Based on vehicles

gasoline		diesel	
$g_1\,(BMW)$	No. of$(g_1) = 7$	$d_1\,(Chevrolet)$	No. of$(d_1) = 30$
$g_2\,(Fiat)$	No. of$(g_2) = 12$	$d_2\,(Mazda)$	No. of$(d_2) = 50$
$g_3\,(Ford)$	No. of$(g_3) = 4$	$d_3\,(Honda)$	No. of$(d_3) = 44$
$g_4\,(Honda)$	No. of$(g_4) = 32$	$d_4\,(Volvo)$	No. of$(d_4) = 12$
$g_5\,(Jeep)$	No. of$(g_5) = 16$	$d_5\,(Kia)$	No. of$(d_5) = 43$
$g_6\,(Volvo)$	No. of$(g_6) = 10$		

Using Equation (3) CE_{vm} (g,d) = ……..g emitted carbon.

Table [4-3]: CO_2 emission from 6 am. to 12 pm. Based on vehicles

gasoline		diesel	
$g_1\,(Mitsubishi)$	No. of$(g_1) = 27$	$d_1\,(Chevrolet)$	No. of$(d_1) = 30$
$g_2\,(Fiat)$	No. of$(g_2) = 12$	$d_2\,(Mazda)$	No. of$(d_2) = 50$
$g_3\,(Ford)$	No. of$(g_3) = 24$	$d_3\,(Merceds - Benz)$	No. of$(d_3) = 44$
$g_4\,(Honda)$	No. of$(g_4) = 52$	$d_4\,(Volvo)$	No. of$(d_4) = 12$
$g_5\,(Jeep)$	No. of$(g_5) = 36$	$d_5\,(Kia1)$	No. of$(d_5) = 43$
$g_6\,(Volvo)$	No. of$(g_6) = 20$	$d_6\,(Kia2)$	No. of$(d_6) = 50$

Using Equation (3) CE_{vm} (g,d) = ……..g emitted carbon.

Table [4-4]: CO_2 emission from 12 pm. to 6 pm. Based on vehicles

gasoline		diesel	
$g_1\,(BMW)$	$\text{No. of}(g_1) = 7$	$d_1\,(Chevrolet)$	$\text{No. of}(d_1) = 30$
$g_2\,(Fiat)$	$\text{No. of}(g_2) = 12$	$d_2\,(Tesla)$	$\text{No. of}(d_2) = 50$
$g_3\,(Nissan)$	$\text{No. of}(g_3) = 4$	$d_3\,(Honda)$	$\text{No. of}(d_3) = 44$
$g_4\,(Honda)$	$\text{No. of}(g_4) = 32$	$d_4\,(Volvo)$	$\text{No. of}(d_4) = 12$
$g_5\,(Jeep)$	$\text{No. of}(g_5) = 16$	$d_5\,(Kia)$	$\text{No. of}(d_5) = 43$
$g_6\,(Volvo)$	$\text{No. of}(g_6) = 10$		

Using Equation (3) CE_{vm} (g,d) = ……..g emitted carbon.

Table [4-5]: CO_2 emission from 6 pm. to 12 am. Based on vehicles

gasoline		diesel	
$g_1\,(BMW)$	$\text{No. of}(g_1) = 17$	$d_1\,(Chevrolet)$	$\text{No. of}(d_1) = 40$
$g_2\,(Fiat)$	$\text{No. of}(g_2) = 22$	$d_2\,(Mazda)$	$\text{No. of}(d_2) = 60$
$g_3\,(Mazda)$	$\text{No. of}(g_3) = 14$	$d_3\,(Toyota)$	$\text{No. of}(d_3) = 10$
$g_4\,(Honda)$	$\text{No. of}(g_4) = 52$	$d_4\,(Volvo)$	$\text{No. of}(d_4) = 12$
$g_5\,(Merceds - Benz)$	$\text{No. of}(g_5) = 36$	$d_5\,(Kia1)$	$\text{No. of}(d_5) = 13$
$g_6\,(Volvo)$	$\text{No. of}(g_6) = 20$	$d_6\,(Kia2)$	$\text{No. of}(d_6) = 50$
		$d_7\,(Honda)$	$\text{No. of}(d_7) = 25$

Using Equation (3) CE_{vm} (g,d) = ……..g emitted carbon. Using Equation (4) the CO_2 emission (in gram) as a result of electricity consumption and vehicles motion through highway has length L = 10km is........g carbon on a random day.

$$\begin{aligned} CE_e(A, E, F_5) &= 4000 \times \left(500 \times \frac{12}{24} \times 1000\right) \times 380 \\ &= 38 \times 10^{10} \text{ g emitted carbon.} \end{aligned}$$

4.3 SMART-STREETSCAPE ELEMENTS (SSSE)

This part will define, explain and identify the properties of Smart-Streetscape Elements (SSSE). The identification of Smart-Streetscape Elements (SSSE) will take place in four phases; the first step is the relation matrix, where it presents the elements of Smart-Streetscape. Phases two is the Cross-sectional surveys, were a data collection through survey were made to collect data regarding the properties of RE and streetscape elements. Phase three is Smart-Streetscape elements database, it presents a database that summarize the elements and properties of SSSE. Finally phase four presents SSSE software, which is a digital tool for Smart-Streetscape elements database.

Smart-Streetscape Elements can be defined as "Sustainable elements that have all the properties of streetscape elements and it also generate clean and efficient energy from RE devices".

4.3.1. Phase One: Relation matrix

This research introduce new elements called Smart-streetscape elements (SSSE) that occurs from integrating RE devices with streetscape elements. Some streetscape elements was integrated with RE sources in previous projects and experiments. These pervious projects and experiments helped the research to identify the types of streetscape elements that can be integrated with RE and create Smart-streetscape elements as shown in table [4-6]. This research targeted the RE sources with low energy density /m^2 such as piezoelectric cells, P.V, biomass, small hydropower and small wind turbines. Large hydropower plants (produced more than 10 MW) and large wind turbines was excluded in this research because there footprint is too large.

The relation matrix presented in Table [4-6] revealed that 48 Smart-streetscape elements are the variables occurred from integrating 11 streetscape elements and 16 sub-elements (with a total 24 streetscape elements) with 7 RE sources.

The number of Smart-streetscape elements which is the number possibilities of integrating streetscape elements with RE devices are presented in Table [4-6], this will provide several options for streetscape designers, architects, landscapers, urban designers and transportation engineers to design their projects using Smart-streetscape elements. The table also revealed that P.V. cells can be integrated with 16 streetscape element and it is the most important device in this study because it creates the largest number of Smart-streetscape elements. Followed by Piezoelectric cells (Pavement) and geothermal they create 7 and 6 Smart-streetscape elements.

Table [4-6] Relation Matrix between Streetscape Elements and RE sources
Source: Moussa, 2017

Streetscape Elements			RE: Piezoelectric cells (P)	RE: Piezoelectric cells (R)	RE: P.V	RE: Biomass	RE: Small Wind Turbines	RE: Geothermal	RE: Hydroelectric
Total			**8**	**5**	**17**	**4**	**4**	**6**	**4**
Streetscape Elements	Street Paving	Crossing		■					
	Street Paving	Road paving	■	■	■			■	
	Street Paving	Sidewalks	■		■				
	Street Paving	Street corners	■	■	■			■	
	Street Paving	Parking lots		■	■	■	■	■	
	Street Paving	Curbs	■	■					
	Vegetation	Trees and Landscape strips				■		■	
	Vegetation	Planting Pots & Planters				■		■	
	Medians		■		■	■	■	■	■
	Lighting				■				
	Street Furniture	Trash receptacles			■				
	Street Furniture	Seating, Benches	■						
	Street Furniture	Bus Shelters			■				
	Street Furniture	Signage			■				
	Street Furniture	Newspaper Racks			■				
	Street Furniture	Bicycle Racks	■		■				
	Street Furniture	Traffic Control Devices			■				
	Street Furniture	Telep. Booths	■		■				
	Rain drainage								■
	Cafe Spaces				■				
	Kiosks				■		■		
	Fountains								■
	Fences, Railings, and Walls				■				
	Public Art				■		■		■

4.3.2. Phase Two: Cross-sectional survey

The Cross-sectional survey is collecting information from the respondents at a single period of time. Cross-sectional surveys usually utilize questionnaires to ask about a particular topic at one point in time. Is a type of observational study that analyzes data collected from a population, or a representative subset, at a specific point and time.

The Cross-sectional survey was conducted to present the different properties of RE devices and streetscape elements. The data were collected from different Egyptian companies that work in the field of constructing streetscape and RE devices such as Curve Streetscape Company, ISolar Company, Three Brothers Company etc. some RE devices are not yet used in Egypt and there is no local companies worked with this materials such as piezoelectric cell, so a strong marketing websites were used to collect data regarding this materials such as Alibaba website and Amazon website. Two Cross-sectional survey were made in this research: The first cross-sectional survey, for RE devices while the second cross-sectional survey were targeting streetscape elements. The first cross-sectional survey were targeting the cost, lifetime, energy produced, area used and annual maintenance cost of each RE device as shown in figure [4-2]. The data collected from different international companies since that there is no a local company works in all RE fields. Moreover, the second cross-sectional survey was corresponding to the size, price, life time and annual maintenance cost of each streetscape elements, presenting the properties of streetscape element as shown in figure [4-2]. “Curve streetscape” company contribute in this research by providing the properties of streetscape elements. It was notice that the cost of RE devices is about 5 times higher than the streetscape elements, which would increase the cost of using SSSE by an average five time more than the regular cost of streetscape elements.

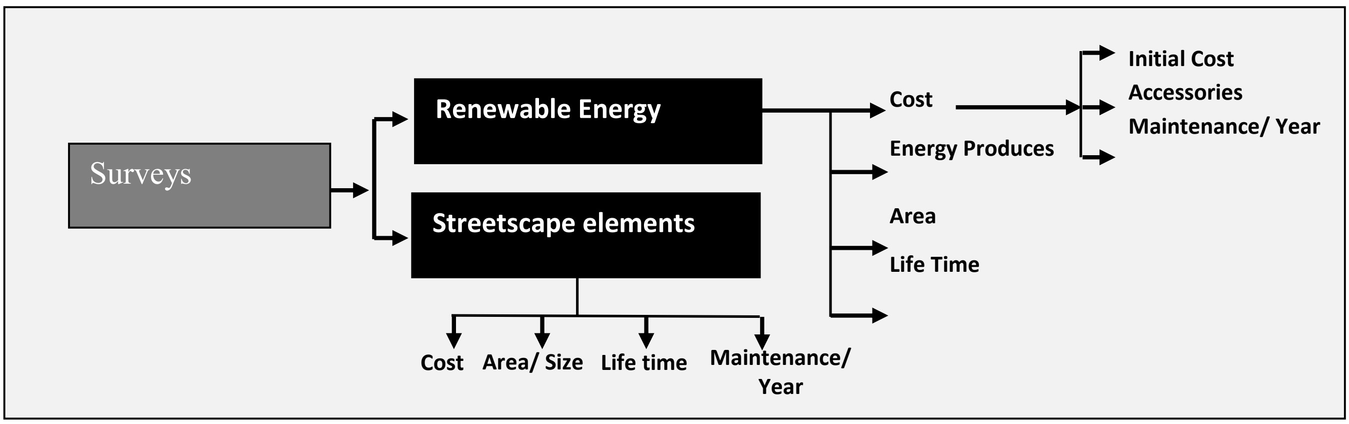


Figure [4-2]: Two Cross-sectional survey targeting the Properties of RE and Streetscape elements

4.3.2.1 Renewable Energy (RE)

The researcher conducted several meetings with twelve managers from different Egyptian companies' to collect data regarding the properties of RE devices. Each company provide the research with a list of properties of renewable energy (RE) devices that they use to work with. The managers of the Egyptian private companies provide the research with information regarding the properties of RE devices, these data has been summarized and analyzed in terms of: initial cost of each device along with the cost of accessories needed to operate that device efficiently, the cost of annual maintenance, the amount of energy produce, the area needed for this device to produce the previous amount of energy, and the life time for this device before it is being replaced as shown in Table [4-7]. Some devices are not wildly used in Egypt such as piezoelectric cells and there has been a lack of data for these devices so a research has been made in international commercial websites such as Alibaba website and manufacturing companies' data sheet has been used to collect the missing data. Each device produce a different amount of energy as shown in table [4-7], this amount of energy is linked to the area of the installed device along with its cost so if a double amount of energy is needed from any device therefore, the area and the price will be calculated as doubled (Moussa, 2017).

Table [4-7]: Properties of Renewable Energy Devices
Source: Moussa, 2017

		Renewable Energy (RE) Properties								
		Cost				Energy Produced		Area		Life Time/Year
	R.E Source	R.E Cost	Accessories		Maintenance /Year	Power	Energy /Day	Size	Weight	
Renewable Energy	P.V	$850	Battery	$840	$85	300 W =0.3 kW	0.3 x12 h = 3.6 kWh	2 m^2	26 Kg	25
			Inventor	$27						
			Cables	$15						
	Biomass	$90,409.0			$40	510 kWh		2.5 m^3		25
	Small Wind Turbines	$1000	Transformer	$150	$20	300 W = 0.3 kW	0.3 x 15h = 4.5 kWh	ф1230 x1090 mm	27 Kg	20
			Capacitor	$10						
	Small Hydro power	$1000	Battery	$840	$50	24-800 kW		Design head = 50-5000 m	Runner Diameter= 0.4- 1.1 m	50
			Inventor	$27						
			Cables	$30						
	piezoelectric cells (Roads)	$6500	Battery	$840	$20	16 kWh		10 m		10-20
			Inventor	$27						
			Cables	$30						
	piezoelectric cells (Pavement)	$1500	Battery	$840	$20	2 kWh		10 m^2		10-20
			Inventor	$27						
			Cables	$30						

Table [4-7] shows that the initial cost of piezoelectric cells are very high in comparing to the energy produces epically piezoelectric cells for roads. While the annual maintenances of P.V cells are higher than any other devices and that due to the dusts and the Egyptian weather. The initial cost of the small hydropower is almost the same as the small wind turbines but it produce more energy than the small wind turbines (Moussa, 2017).

4.3.2.2 Streetscape

An interview took place with the general manager and the financial manager of Curve Landscape Company; this interview made in February 2017. The head manager of Curve Landscape Company was asked 38 question, 34 question was related to the prices and properties of streetscape elements which was constructed previously by the company, while 4 questions were restated to the company biography.

The data presented in Table [4-8] summarize the different properties of streetscape elements. The data were divided into five parts; product description, area, cost, lifetime and annual maintenance. The data provides the local initial and maintenance cost of each element along with the area needed to install this element and its life time as shown in Table [4-8] (Moussa, 2017).

Table [4-8]: properties of streetscape element from data survey
Source: Moussa, 2017

Streetscape Elements		International Consultant				
			Properties			
		Material name	Cost	Maintenance/ year	Lifetime/ year	Size
Street Paving	Crossing	(OEM)cargo trail	$1,000 - 6,000	2$	25	2400x6000 mm
	Road paving	(OEM)cargo trail	$1,000 - 6,000	2$	15	2400x6000 mm
	Sidewalks	natural granite pavement	5m^2	2$	15	10x20x5/10cm
	Street corners	(OEM)cargo trail	$1,000 - 6,000	2$	25	2400x6000 mm
	Parking lots	(OEM)cargo trail	$1,000 - 6,000	2$	50	2400x6000 mm
	Curbs	natural granite pavement	5 m^2	2.5$	25	10x20x5/10cm
Vegetation	Trees & Streetscape strips	natural grass for garden home lawn	$1 - 12 / m^2	4$	70	Customized
	Planting Pots & Planters	natural grass for garden home lawn	$1 - 12 / m^2	4$	70	Customized
Medians		natural grass for garden home lawn	$1 - 12 / m^2	4$	100	Customized
Lighting+ solar cells		High quality new upgraded all in one energy saving high brightness solar street light	300	1$	25	Customized
Street Furniture	Trash receptacles	custom made stainless steel trash can/street garbage bin/outdoor waste container	$1.5 - 3.5	0.25$	10	customized
	Seating, Benches	Durable Steel Park bench/ outdoor metal bench/ Patio metal bench	$100 - 200	1$	10	1520x650x810 mm
	Bus Shelters	Modern City Bus Shelter With Solar Power System And LED Scrolling Light Box	$600-900/Unit	1.5$	25	12070x3050x1400mm

	Signage	Standing Advertising Aluminum Street Prisma Signage	$60-120 / m^2	0.04$	15	customized
	Newspaper Racks	Flooring acrylic outdoor newspaper racks	$50	2$	25	280x320x800mm
	Bicycle Racks	modular bicycle parking rack	$4-6.5	2$	25	400x152x220mm
	Traffic Control Devices		$105.0	4$	10	200mm
	Telep. Booths	Traffic police booth kiosk booth/container house	100	3$	10	1.2x1.5x2.4m
Rain drainage		Outdoor Rain Storm Composite Water Grates for Drainage	US $20	6$	30	400x600
Cafe Spaces			$1 - 12 / m^2	2$	40	Customized
Kiosks		Shopping mall kiosk mobile kiosk design with 3D kiosk design	$150 - 500 / m^2	3$	15	Customized
Fountains		Garden Water Fountain Outdoor Fountain Led Garden Fountain	2000	12$	50	Customized
Fences, Railings, and Walls		Q110969 artificial plant wall garden decor streetscape plants artificial living wall	$75 - 200 m^2	5$	70	Customized
Public Art			1000	8$	50	Customized

4.3.3. Phase three: Smart-Streetscape elements (SSSE) database

The data collected from the relation matrix and Cross-sectional surveys were used to create SSSE database. To calculate the properties of SSSE, a comparison between the area of RE devices and the area of streetscape elements was made. The minimum area that can be used for this integration was entered as SSSE area & a new calculation has been made for the cost and the power produced for the new area.

The cost of SSSE is the sum of the initial cost of streetscape elements and the initial cost RE device plus the cost of the accessories need to operate this device. The annual maintains cost is the sum of the RE device and streetscape elements. Finally the lifetime, is comparing the lifetime of Re device with streetscape elements and the less lifetime were chosen to be the minimum lifetime of SSSE.

Table [4-9] present all the properties of Smart-streetscape elements [SSSE], the properties is divided into the total cost, minimum areas need, energy produced by day, the annual maintenance cost and finally is the lifetime of this element. The results of SSSE properties shows that SSSE will live for at least 10 years and generate energy efficiently but it will cost more than the normal streetscape elements by an average 10 times more than the initial price of streetscape element. The minimum annual maintenance cost of SSSE is 21$ while the maximum annual maintenance cost of SSSE is 93$. The minimum energy produced /day for SSSE is from piezoelectric cells (pavements), it produce 2 kWh for 10 m^2 area although geothermal energy produces 24 kWh for 1.5m^2 area. Geothermal energy can be considered the element that produced maximum energy /day but it is a rare source of energy and it doesn't occur in most sites.

Table [4-9]: properties of Smart-streetscape elements SSSE
Source: Moussa, 2017

Streetscape Elements		Renewable energy (RE) devices	SSSE Properties				
			Total cost	Area	Energy / Day	Maintenance cost / Year	Life time
Street Paving	Crossing	Piezoelectric cells (R)	$7,397	10 m	16 kWh	$22	15 years
	Road paving	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$22	15 years
		Piezoelectric cells (R)	$7,397	10 m	16 kWh	$22	15 years
		P.V	$1,871	2m^2	3.6 kWh	$87	15 years
		Geothermal	$1,780,105	1.5 m^2	24 kWh	$52	15 years
	Sidewalks	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$22	15 years
		P.V	$1,742	2 m^2	3.6 kWh	$87	15 years
	Street corners	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$22	15 years
		Piezoelectric cells (R)	$7,397	10 m	16 kWh	$22	15 years
		P.V	$1,871	2 m^2	3.6 kWh	$87	25 years
		Geothermal	$1,780,105	1.5 m^2	24 kWh	$52	25 years
	Parking lots	Piezoelectric cells (R)	$7,397	10 m	16 kWh	$22	15 years
		P.V	$1,871	2 m^2	3.6 kWh	$87	25 years
		Biomass	$90,583	2.5m^3	510 kWh	$42	26 years
		Small Wind Turbines	$1,993	12 m^2	4.5 kWh	$22	20 years
		Geothermal	$1,780,105	1.5 m^2	24 kWh	$52	25 years
	Curbs	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$22.5	15 years
		Piezoelectric cells (R)	$7,397	10 m	16 kWh	$22.5	15 years
Vegetation	Trees and Landscape strips	Biomass	$90,424	2.5m^3	510 kWh	$44	26 years
		Geothermal	$1,780,009	1.5 m^2	24 kWh	$54	25 years
	Planting Pots & Planters	Biomass	$90,424	2.5m^3	510 kWh	$44	26 years
		Geothermal	$1,780,009	1.5 m^2	24 kWh	$54	25 years
Medians		Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$24	15 years
		P.V	$1,744	2 m^2	3.6 kWh	$89	25 years
		Biomass	$90,424	2.5m^3	510 kWh	$44	26 years
		Small Wind Turbines	$1,232	ϕ12m^2	4.5 kWh	$24	20 years
		Geothermal	$1,780,009	1.5 m^2	24 kWh	$54	25 years
		Hydroelectric	$1,903	ϕ1.1m	25 kWh	$54	50 years
Lighting		P.V	$300	2 m^2	3.6 kWh	$86	25 years
Street Furniture	Trash receptacles	P.V	$1,742	2 m^2	3.6 kWh	$85.25	10 years
	Seating, Benches	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$21	10 years
	Bus Shelters	P.V	$1,803	2 m^2	3.6 kWh	$86.5	25 years
	Signage	P.V	$1,852	2 m^2	3.6 kWh	$85.04	15 years
	Newspaper Racks	P.V	$2,848	2 m^2	3.6 kWh	$87	25 years
	Bicycle Racks	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$22	15 years
		P.V	$1,864	2 m^2	3.6 kWh	$87	25 years
	Traffic Control Devices	P.V	$1,837	2 m^2	3.6 kWh	$89	10 years
	Telep. Booths	Piezoelectric cells (P)	$2,397	10 m^2	2 kWh	$23	10 years
		P.V	$779.4	1.8m^2	1.62kWh	$88	10 years
Rain drainage		Hydroelectric	$1,917	ϕ1.1m	25 kWh	$56	30 years
Cafe Spaces		P.V	$1,744	2 m^2	3.6 kWh	$87	25 years
Kiosks		P.V	$2,032	2 m^2	3.6 kWh	$88	15 years
		Small Wind Turbines	$1,310	ϕ12m^2	4.5 kWh	$23	15 years
Fountains		Hydroelectric	$3,897	ϕ1.1m	25 kWh	$62	50 years

Fences, Railings & Walls	Biomass	$90,484	2.5m^3	510 kWh	$45	26 years
Public Art	P.V	$2,732	2 m^2	3.6 kWh	$93	25 years
	Small Wind Turbines	$2,160	ɸ12m^2	4.5 kWh	$28	20 years
	Hydroelectric	$2,897	ɸ1.1m	25 kWh	$58	50 years

4.3.4. Phase four: Smart-Streetscape elements (SSSE) Software

Moussa (2017) presented the properties of Smart-streetscape elements (SSSE), but the database presented in table Table [4-9] was very confusing to the architects and landscape designers. This research presents a new software called "Smart-Streetscape elements (SSSE)" software. The main aim of this software is to help the streetscape designers, architects, urban designers and transportation engineering's to use the SSSE sustainable elements in efficient way. This software will help the streetscape designers, architects, urban designers and transportation engineering's to know the properties of SSSE elements and to choses suitable SSSE elements for their designs in an easy way. "Smart-Streetscape elements (SSSE)" software is a user-friendly software were any user can use it without training, this software will help the user to use energy generating streetscape elements instead of aesthetic and functional streetscape elements knowing that SSSE elements will preserve the aesthetic and functional benefits of streetscape elements. The data presented before in the database section has been used as the database of SSSE software. The software work flow is divided into three phases; phase one data input, phase two process and phase three is data output as shown in the below figure [4-3].

- ***Concept***

The concept of creating "Smart-Streetscape elements (SSSE)" software is based on creating a use-friendly digital tool that helps the streetscape designers, architects, urban designers and transportation engineering's to choose the most suitable SSSE in easy way and with less effort according to their budget, area or even to the energy need. This software should encourage the streetscape designers, architects, urban designers and transportation engineering's to use this sustainable elements and benefit from its non-stop energy production.

The work flow of this software is divided into three phases. Phase one data input; the user will be asked to enter the coordinates of this site and he/she will answer five questions addressing the site conditions. Phase two process; the software will automatically use the entered coordinates to identify the site by connecting to google map, from the questions the software will minimize the number of SSSE elements that can be used in the site depending on the answers given by the user. Phase three is data output; the output is a database for all SSSE elements that can be used in the site along with the properties (area, cost, annual maintain ace cost, lifetime and energy produced) of each element as shown in figures [4-3] and [4-4].

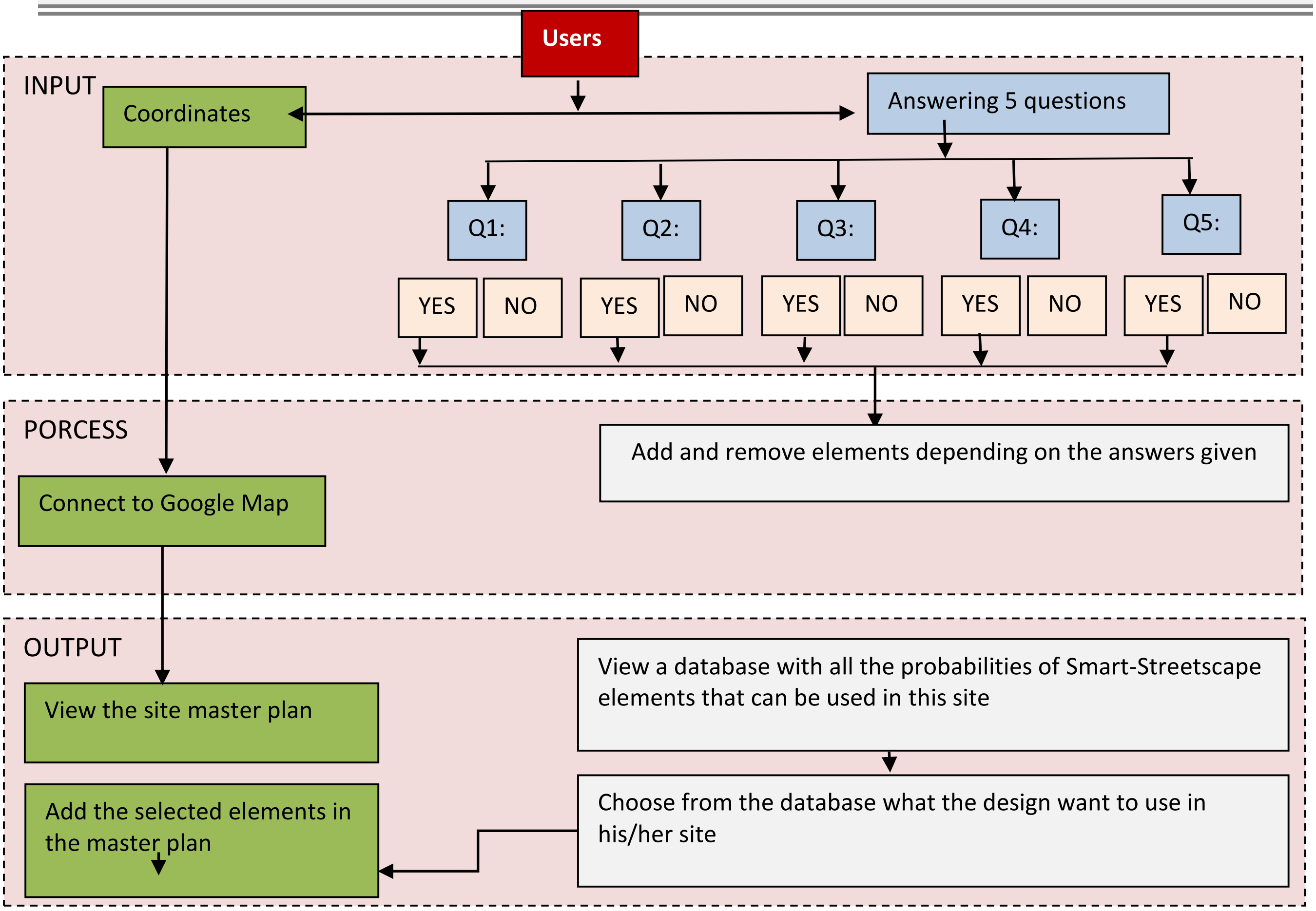


Figure [4-3]: "Smart-Streetscape elements (SSSE)" software workflow
Source: By researcher

- ***Algorism***

Smart -Streetscape elements (SSSE) software were built by Programming language PHP and the database used Mysql database. Smart-Streetscape elements (SSSE) software was create to serve the purpose of this research, which is encourage the streetscape designers, architects, urban designers and transportation engineering's to use Smart-Streetscape elements instead of using normal streetscape elements in an easy way and without needing the consultants of mechanical and electrical experts in the field of renewable energy. The algorithm of Smart-Streetscape elements (SSSE) software is presented in this section in figure [4-4]. The algorithm along with the work flow presented in figure [4-3] describe how this software works and the benefits of SSSE software.

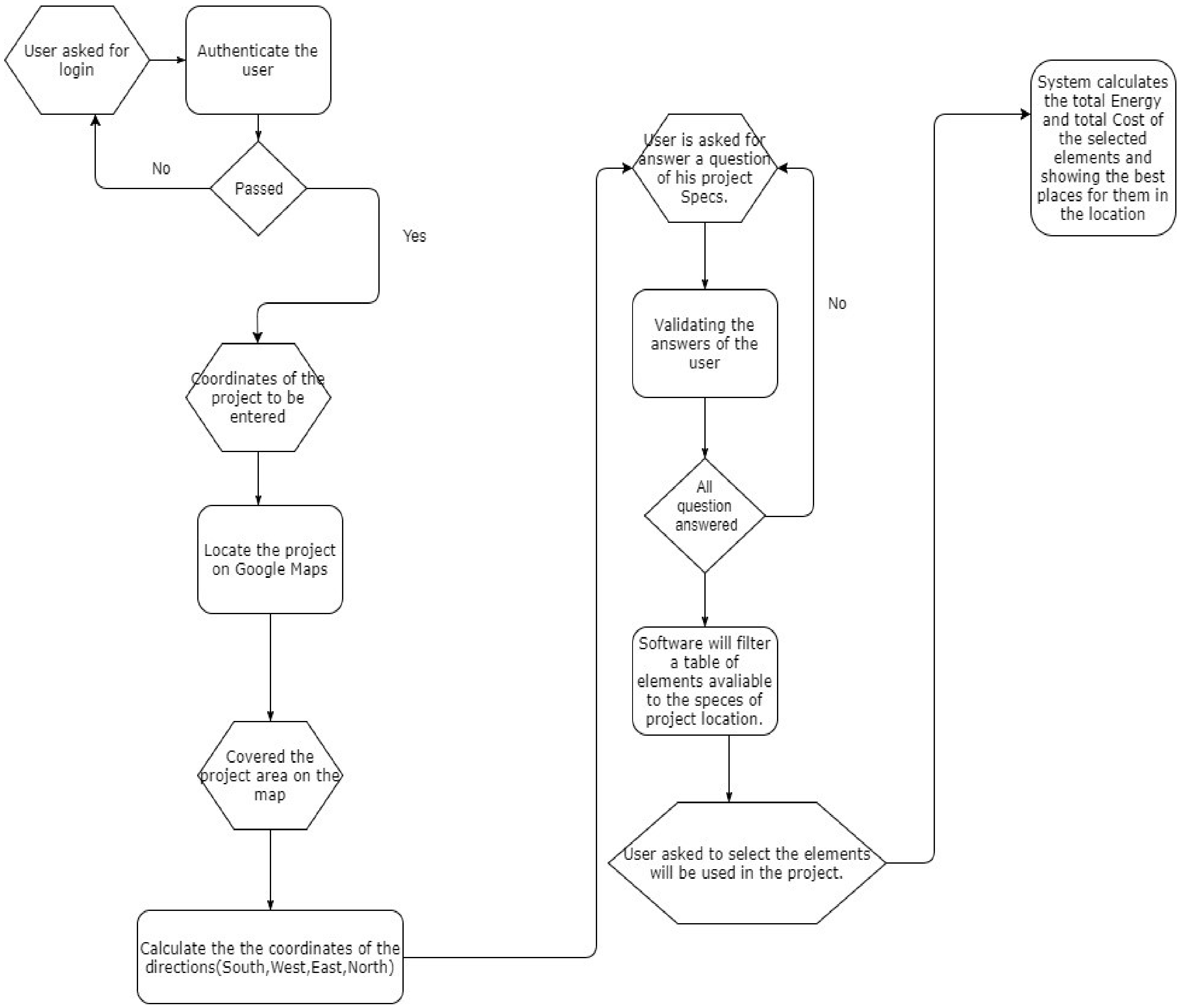


Figure [4-4]: The algorithm of Smart-Streetscape elements (SSSE) software
Source: By researcher

- ***Interface***

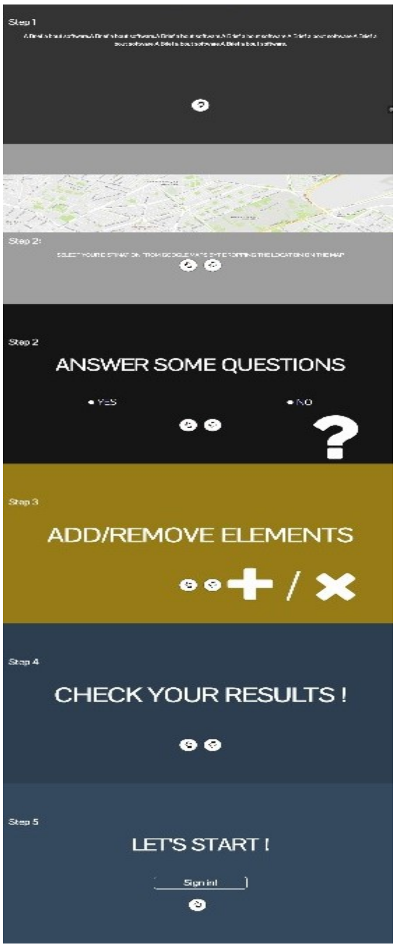


Figure [4-5]: The main page of Smart-Streetscape elements software
Source: SSSE Software

SSSE software is a user-friendly software with easy interface as shown in figure [4-5]. The first step for using this software is to enter the coordinates of your project location; SSSE software are connected to google map and by entering the project coordinates the software will automatically identify the site and the site surroundings as shown in figure [4-6].

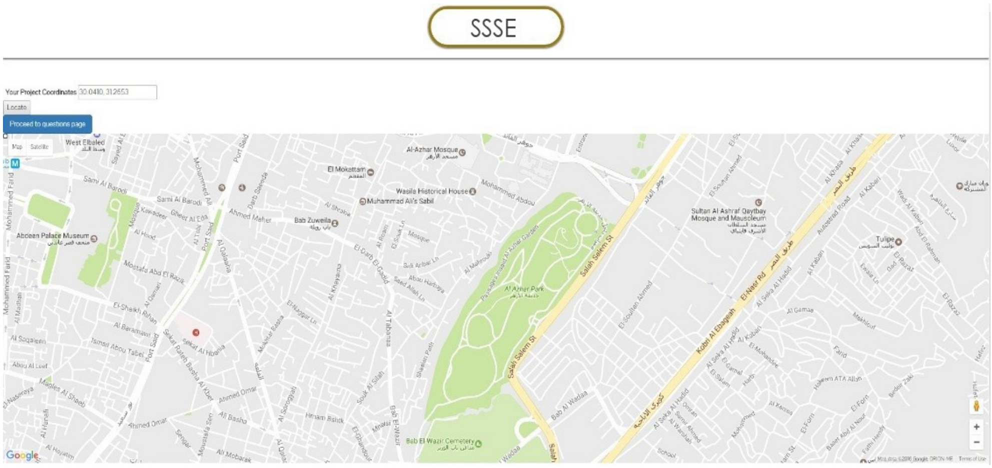


Figure [4-6]: Entering the coordinates in Smart-Streetscape elements software
Source: SSSE Software

The user should answer five questions, the software will not run until these five questions are answered. The user will choose to answer these questions by Yes or No as shown in figure [4-6]. The five questions are 1- is there a high way road in front of your land?, 2- Is there any natural running water source in or surrounding your land?, 3- Is your land located in a geothermal location?, 4- Is the wend speed in your land are more than 1.5m/s?, 5- dose your project produce any agriculture wastes? After answering the above questions the program will run and a database will be presented in the form of table and a figure as an outcome for the software as shown in figure [4-7].

SSSE

PLEASE Select you need for your project

#	Streetscape Elements	Renewable energy	Streetscape properties(Area)	Streetscape properties(Cost)	R.E Properties(Area)	R.E Properties(Energy/ Day)	R.E Properties(Cost)	Total cost	mim. Area	Energy / Day	Maintenance cost / Year	Life time/ Year
	Road Paving	Piezoelectric cells (Pavement)	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		Piezoelectric cells (Roads)	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		P.V	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		Geothermal	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
	Street Corners	Piezoelectric cells (Pavement)	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		Piezoelectric cells (Roads)	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		P.V	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20
		Geothermal	0	0	10 m2	2 KWh	$1500	$150	1 m2	0.2 KWh	$20	10-20

Figure [4-7]: Smart-Streetscape elements and properties
Source: SSSE Software

The database will present SSSE elements that can be used in the site. The properties of SSSE element such as the initial cost of this element, the area need for this element, the lifetime of this element, the annual maintained of this element and finally the amount of energy produced daily from this element will also be presented. The user should chose elements from the database presented by the software based on the cost or amount of energy needed in the project and these elements will be allocated automatically in the figure. The figure will present the layout of the site (taken from google earth) identifying the chosen Energy-scape elements that been chosen by the user to be used in his/her project as shown in the below figure [4-8].

SSSE

Your selected Elements

Total Cost:102547.5

Total Energy:531.6

Landscape Elements	Renewable energy	Total cost	mim. Area	Energy / Day	Maintenance cost / Year	Life time/ Year
Piezoelectric cells (Roads)	Trails	7397.0000 Edit	10.0000 Edit	16.0000 Edit	20.0000	15
Piezoelectric cells (Pavement)	Pavements	2397.0000 Edit	10.0000 Edit	2.0000 Edit	20.0000	15
Biomass	Open Space	90421.5000 Edit	2.5000 Edit	510.0000 Edit	40.0000	26
P.V	Kiosks	2332.0000 Edit	2.0000 Edit	3.6000 Edit	85.0000	25

Figure [4-8]: Applying Smart-Streetscape elements on the site
Source: SSSE Software

4.4 SUMMARY

This chapter identified a new model for calculating highway carbon emissions as well as it identify an new system called Smart-streetscape elements (SSSE), which is a sustainable elements produced from integrating renewable energy (RE) devices with streetscape elements. These sustainable elements preserve the aesthetic and functional benefits of streetscape elements as well as it produced a clean and efficient energy from RE devices.

This chapter is a background from the next chapter which is chapter five: the case study chapter, in which an application will take place using the model and system presented in this chapter to help in turning New Aswan city to a low carbon and sustainable city, which Is the main goal of this research

CHAPTER FIVE

RESEARCH APPLICATION, DISCUSSION AND CONCLUSION

5.1 INTRODUCTION

This chapter aims to apply the presented methodology on a study area in great Cairo. The aim of the research is to reduce the carbon emissions produced from roads and transportation sectors, in order to reach the research goal an application will be set to measure the amount of carbon emission produced from existing Road in Grate Cairo and the amount of carbon reduces from applying the proposed method. The proposed method are based on integrating streetscape elements with renewable energy generation devices and create new devices called "Smart-Streetscape" devices as it has been presented previously in chapter four. This research will examine the efficiency of using Smart-Streetscape device instead of regular streetscape elements by applying it in existing study area and study the amount of carbon reduced. Moreover, the chapter will study the efficiency of the user-friendly web base application which is called "Smart-Streetscape software (SSSE)" towered the user perception.

The application applied in "El-Sherock city" the study area of this chapter were divided into three parts; the first part is a survey that measure the efficiency and visibility of SSSE software. The second part is calculating the amount of Carbon emissions produced from the study area. Finally, the third part is applying Smart-Streetscape elements in the study area (El-Shrouck city, Egypt) to measure its efficiency and the amount of CO_2 reduced.

A main street in "El-Shrouck city" has chosen to be the research study area, in order to calculate the cost, energy produced and area used from using Smart Streetscape elements, which occurs from integrating streetscape elements with renewable energy generation devices. The results were analysed in order to study the efficiency of integrating these two systems (streetscape elements & renewable energy devices). The result will be present in this chapter in the form of graphs, charts and tables, which clarify the outcome of the study.

5.2 STUDY METHODS

This research uses a descriptive and correlation methods to investigate the influence of Smart-Streetscape on cost, energy produced and area used by integrating streetscape elements with renewable energy (RE) sources. The empirical section of this research divided into two parts; part one is the validating of SSSE software which was presented in the previous chapter and part two is the case study which is divided into phase one and phase two as shown in Table [5-1].

Table [5-1]: The structure of chapter five

<table>
<tr><th colspan="2"></th><th>Method</th><th>Equipment</th><th>Purpose</th></tr>
<tr><td colspan="2">Part One : Validating SSSE software</td><td>Descriptive</td><td>Questionnaire</td><td>Measuring the efficiency and visibility of SSSE software</td></tr>
<tr><td rowspan="3">Part Two : Case study</td><td>Phase one: Measuring the existing level of Carbon emission in a study area</td><td rowspan="3">Correlation</td><td>CO_2 Emission model</td><td>Calculation the Amount of CO_2 in the study area</td></tr>
<tr><td rowspan="2">Phase Two: Designing the study area using Smart-streetscape elements</td><td rowspan="2">SSSE software</td><td>Calculation the Amount of CO_2 reduced in the study area</td></tr>
<tr><td>Study the efficiency of Smart-streetscape elements</td></tr>
</table>

5.3 PART ONE: VALIDATING SSSE SOFTWARE

This research uses an empirical method for investigating the efficiency of SSSE software. The empirical method was divided into three phases targeting professional architecture and landscape designers. In the first phase which is called “Stage One”; the survey asked the participant to design Smart-Streetscape elements in a specific main road in El-Sherock city using Smart-streetscape database as a tool to present the properties of the chosen elements. While in the second phase which is called “Stage Two”; the same participants were asked to design a main road in El-Sherock city using SSSE software as a designing tool to present the elements properties. Finally in the third and final phase “Stage three”’ the participant were given a questioner to measure their experience before and after using the software. The task was to use as less Smart-Streetscape elements as possible to generate enough energy for this park to operate efficiently. Knowing that the participants didn't take any training regarding the presented software, they were only introduced to the objectives of the software and they were asked to follow the steps.

5.3.1. Study Area

The purpose of this research is to study the opinions of the professional's architects and Streetscape designers toward the efficiency of SSSE software. The survey took place in private universities located in Cairo-Egypt, such as the "British university in Egypt" (BUE) and "Arab Academy for Science, Technology and Maritime Transport College of Engineering and Technology" (AASTMT). The study targeted professors, Associate professors, lecturers and teaching assistants.

5.3.2. Characteristics of Participants

The research participants exposed to two test in this research depending on the research methodology, after that they were given a questionnaire to summarize their experience toward the tests and to measure the efficiency of SSSE software. The participate must run the three stages, any participate didn't run one stage was excluded from the research results. The participants was chosen from a group of professional architects and landscape designers. The details of the participants will be shown in the following subsections.

The research sample consist of 56 architects, landscapers and streetscape designers who were willing to participate in the research, in order to measure the rate of effectiveness of SSSE software. The sample started with more than 78 architects and landscape designers but the participants who participated in the three stages were 56 out of 78. This survey took place during February 2018. The distribution of the participants, social and demographic characteristics, such as gender, age, marital status and education level are shown in Table [5-2].

Table [5-2]:Social and Demographic characteristics of the research participants

GENDER	
Type	Percentage
Male	42%

AGE	
Range	Percentage
20-29	35%
30-40	32%

EDUCATION	
Education level	Percentage
PHD degree	44%
Master degree	26%

Female	58%	Above 40	33%	BSC of engineering	30%

5.3.3. Data Collection Questionnaires

Data collection in one of the most important step in any research, it controls the data which will be analyzed; if a wrong data was collected, the research will be useless. In this research, questionnaires were used in order to collect data. Questionnaires were chosen to be the method of data collection because the study was aiming to measure the simplicity of extracting data from a proposed web base application that present Smart-Streetscape elements and its properties. The main goal of the web base application is to encourage architects, landscapers and streetscape designers to use Smart-Streetscape elements in their designs, that's why the questionnaire was targeting architects and landscape professors.

A short questionnaire has been used in this research, which consists of 14 questions in order to measure the rate of simplicity, accuracy, time saving, and efficiency of user friendly web base application (SSSE software). The questionnaire was divided into two parts; the first part consisted of five questions corresponding to personal characteristics of subjects including gender, career, age and years of experiences, the second part consisted of fourteen questions corresponding to the experience that the participant felt during the two design tests (test 1: designing Smart-Streetscape elements in a main road in El-Sherock city using Smart-Streetscape database; test 2: designing Smart-Streetscape elements in a main road in El-Sherock city using SSSE software). The 14 questions were divided into 7 questions related to SSSE software while the other 7 questions are related to Smart-Streetscape database. The questions were related to speed of design (time saving), feasibility, ability to change or modify the properties, software interface, and efficiency.

The participants were asked to indicate the rate of effectiveness of SSSE software from 'totally disagree' (5 points) to 'totally agree' (1 point). Finally, questions were randomly ordered in the questionnaire to elicit more objective answers from the respondents.

5.3.4. Procedures

The research procedures were different from stage to another. The participant were asked to design Smart-Streetscape elements in a main road in El-Sherock city and present the properties of the chosen elements, taking into consideration the initial cost of Smart-Streetscape elements and the amount of energy produced. The participant were asked to choose the most suitable elements to their sites, moreover to calculate the initial cost of all Smart-Streetscape elements used in there project, to calculate the energy generate from Smart-Streetscape elements, and to calculate annual maintenance cost that the park should pay to insure the efficiency of operating Smart-Streetscape elements. The goal was to pay as less money as possible to generate enough energy for this park to operate efficiently.

In stage one: the participant were asked to design Smart-Streetscape elements in a specific main road in El-Sherock city using Smart-Streetscape database as a guiding tool. Since that the initial cost of renewable energy is very high and Smart-Streetscape elements generate energy from renewable energy that makes the initial cost of Smart-Streetscape elements high. The challenge that faced the participants was to choose the most suitable Smart-Streetscape elements in their site according to power generation and cost; to choose elements that generate enough energy to operate the park efficiently and to pay as less money as possible.

In stage two: the participant were asked to design Smart-Streetscape elements in the same main road in El-Sherock city using a user friendly web base application (SSSE software) as a guiding tool. The participants were asked to choose elements that generate enough energy to operate the park efficiently and to pay as less money as possible.

In stage three: was made by structured interview conducted during February 2018. The participants were given a questionnaire consist of 14 questions in order to measure the rate of simplicity, time saving, and efficiency of SSSE software. The interviewing process was very simple because the participants were educated and had a scientific background.

The 56 participants were architects, urban designers and streetscape designers representing academic staff, professionals and postgraduate students. The participants were chosen carefully depending on their educational level. The questionnaire took place in private universities such as the “British university in Egypt” (BUE) and “Arab Academy for Science, Technology and Maritime Transport college of Engineering and Technology” (AASTMT). The study targeted professors, lecturer, and teaching assistants. Each participant was asked to answer the questions during the interview and every question was described to them before answering it in order to make sure that each participant understood every question thoroughly.

All the answers were collected and entered to SPSS program, a statistical analysis program, in order to know the opinion of the professionals about the proposed software. SPSS program was used to calculate the mean value and the standard deviation value.

5.3.5. Results

This section introduces the results of the statistical analysis of the data which was collected during the three stages. The purpose of this survey is to know the professional's opinions of architects and landscape designers toward the efficiency of SSSE software in helping the users in designing Smart-Streetscape elements efficiently. The results of the first stage revealed that 32% of the architect's and landscape designers choose Smart-Streetscape elements according to the order in the database. Moreover, 23% chose the elements according to their initial cost (they chose the elements with low initial cost). While 31% chose the Smart-Streetscape elements randomly and 14% chose randomly from the elements that can be integrated with landscape elements that is exit in the park as shown in figure [5-1]. It was noticed that the participants needed 1 hour and 35 minute to complete the test (the first participant submit the test after 45 min and the last participant submitted the test after 95 min.).

In stage two 100% of the participants choose Smart-Streetscape elements according to the elements with low initial cost and produced large amount of energy that has been proposed to them by SSSE software. Simply the participants choose one or two elements will low initial cost, they stated the amount of energy needed, they left the software to calculate the area needed to install this element in there site and finally they proposed the locations of this elements according to the suggestion that was given to them by SSSE software. It was noticed that the participants completed the test in 20 min.

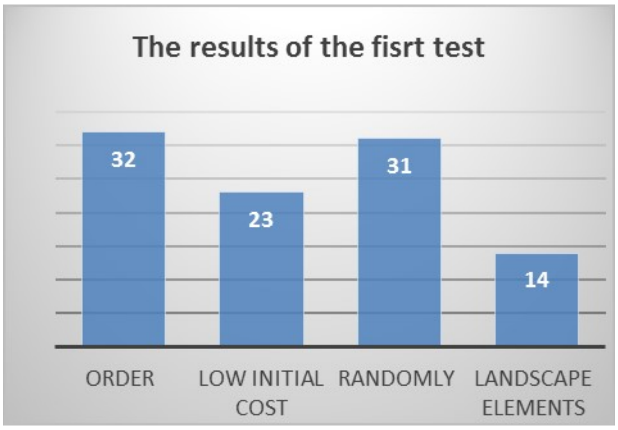


Figure [5-1]: The criteria that was used by the participants in stage 1
Source: By researcher

In stage three, the participants were given a questionnaire that summarizing their experience in the two tests (stage one and stage two). The following charts revealed the experience of the participants toward using SSSE software and Smart-Streetscape database as a designing tools for designing Smart-Streetscape element. Some aspects where taken into consideration for the questionnaire process; these aspects are the "Simplicity, Accuracy, Time Saving, Efficiency, Design Modification, Elements Location and Needs for Background Information". Simplicity: represents the simplicity in using the designing tools (software or database) to design Smart-Streetscape elements, Accuracy: measures the calculations of quantity survey for different Smart-Streetscape elements that has been used with minor errors, Time Saving: is the ability to design Smart-Streetscape elements in little time, Efficiency: is to choose and design the most suitable Energy-scape elements to the site, Design Modification: is the flexibility to change or modify the calculations of the chosen elements with less errors, Elements Location: represents the ability that the design tools gives to the participants to choose the most suitable location for the chosen Smart-Streetscape elements, Needs for Background Information: is the needs for previous expertise that the participants must have in the field of landscape and renewable energy before using the designing tools (software or database).

In order to understand the significant of SSSE software on the participants it was decided to choose the aspect that was presented previously as a measuring criteria toward the efficiency of SSSE software. When the participants state it 2 or less than 2 in any aspect, it represents the highest satisfaction aspects that satisfy the participants. The total number of response is 5 and 3 is the moderate effect so we chose 2 which is less than the moderate to prove that this aspect is satisfy by the participants in using the designing tools (software; database). 4 or more than 4 is the lowest satisfaction aspects that satisfy the participants.

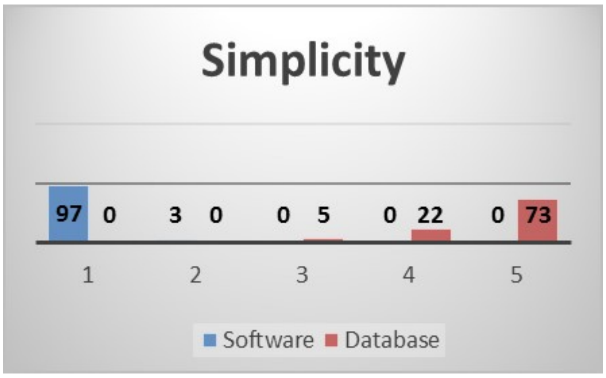


Figure [5-2]: A comparison between the simplicity of SSSE software and database
Source: Bv researcher

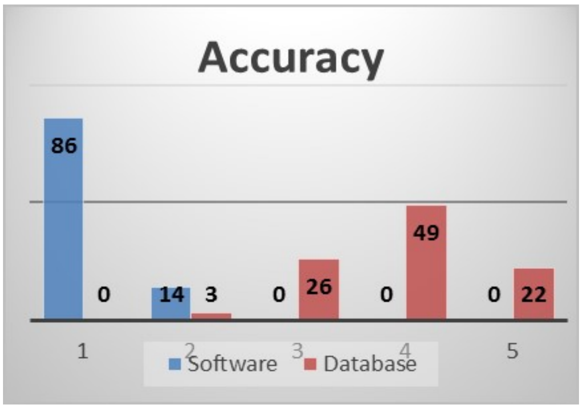


Figure [5-3]: A comparison between the Accuracy of SSSE software and database
Source: By researcher

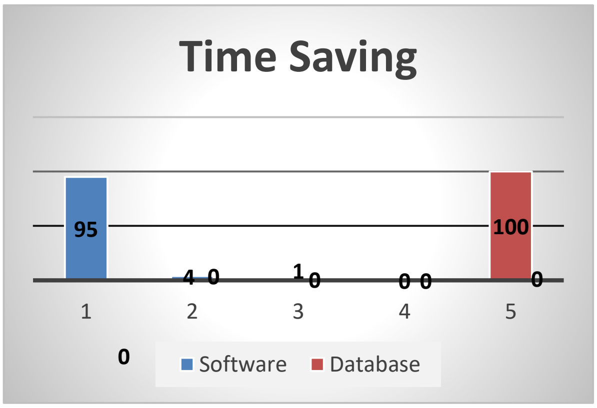


Figure [5-4]: A comparison between the time spend in using SSSE software and database
Source: By researcher

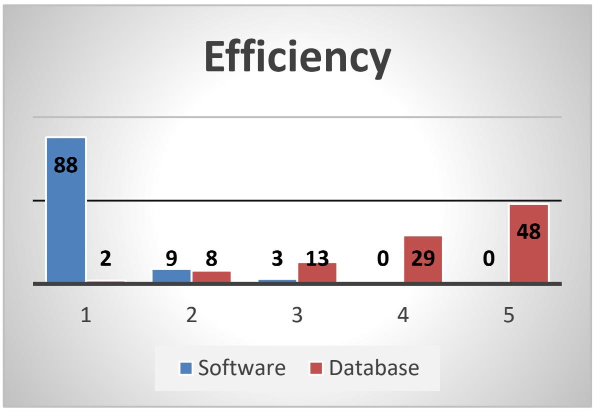


Figure [5-5]: A comparison between the efficiency in using SSSE software and database
Source: By researcher

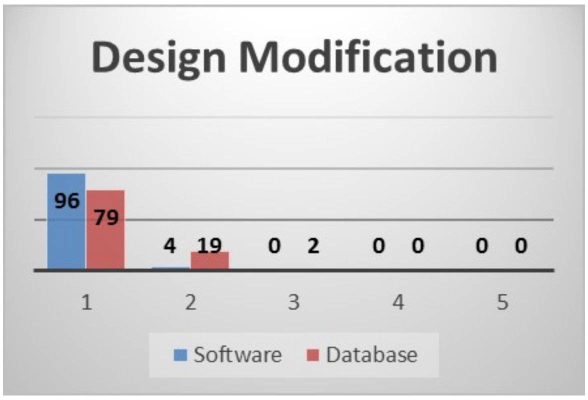


Figure [5-6]: A comparison between the applicability in modifying the design using SSSE software and database
Source: By researcher

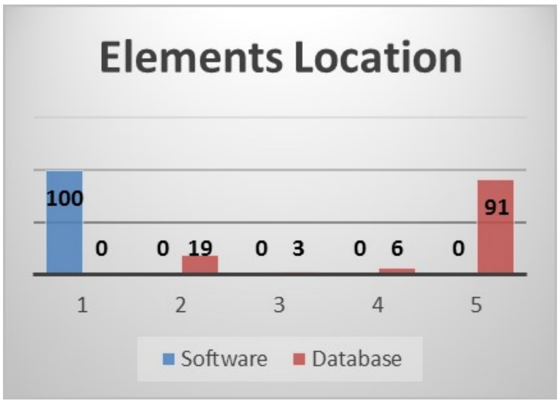


Figure [5-7]: A chart presents that SSSE software provide a location for Smart-Streetscape elements which helps the users
Source: By researcher

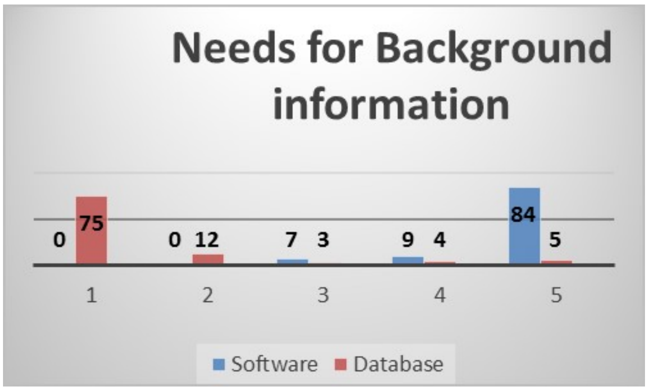


Figure [5-8]: identifying chart for needs of background information toward Renewable energy during using Smart-Streetscape elements and database
Source: By researcher

The response of the participants was very positive toward Smart-Streetscape elements and was very negative toward the use of the database. All the participants agreed that the database was very confusing and not understandable will the software is very efficient and easy to use. The response of the questioner was summarize as shown in figures (5-2; 5-3; 5-4; 5-5; 5-6; 5-7and 5-8).

5.4 PART TWO: CASE STUDY APPLICATION

5.4.1. Study Methods

This research uses an empirical method for measuring the level of carbon emission in the study area more over it present a solution for reducing the carbon emissions using Smart-Streetscape elements. This empirical method consists of two phases. Phase one; is calculating the existing level of carbon emission using statistical model, that has been designed and presented in the previous chapter (chapter 4). Phase two; is redesigning the study area using Smart-Streetscape Elements to reduce the carbon emissions. The results will be presented in this chapter providing a long term scenario for reducing the carbon emissions as well as a short term scenario in terms of amount of energy generated and the amount of carbon emission reduced.

5.4.2. Study Area

Mubarak road in El-Sherouk city, Cairo-Egypt has been chosen randomly to be the study area of this research because it is one of the most crowded and important roads in the Egyptian new urban settlements such as El-Sherouk city. In addition, this street was chosen due to the availability of data.

Mubarak road represent a gateway that connects two highway roads which are Cairo-Ismalia Desert Road and Cairo-Suez Desert Road, which makes Mubarak road one of largest density roads in El-Sherouk City as shown in figure [5-9 and 5-10]. El- Sherouk city is one of the most crowded new urban settlements in Egypt due to the location of two private high educational facilities “the British university in Egypt (BUE)” and “El-Sherouk Academy” as shown in figure [5-10].

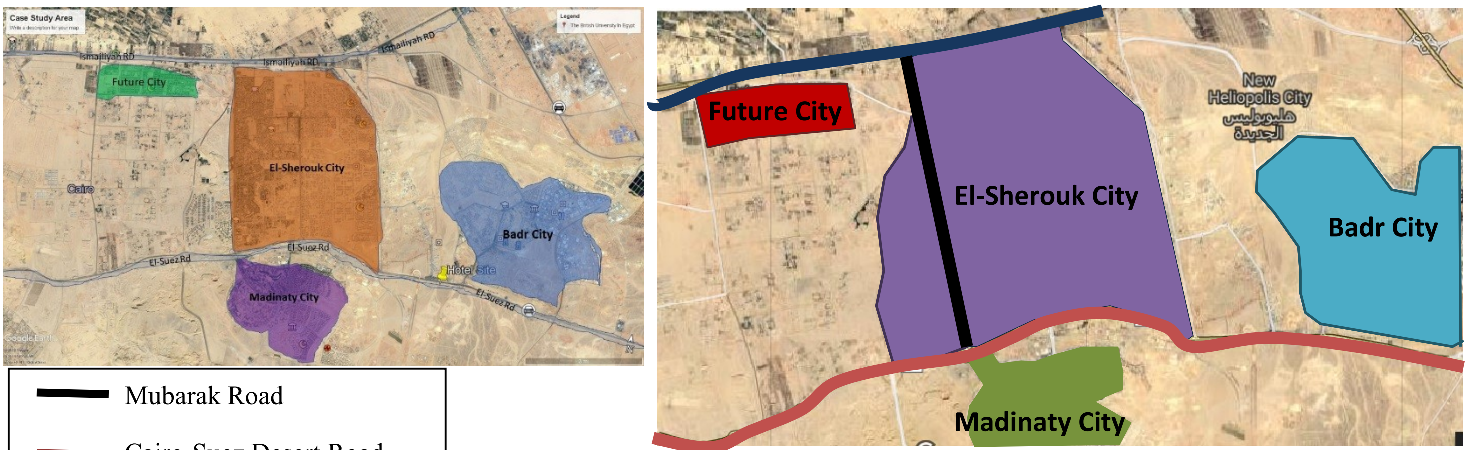


Figure [5-9]: The location and surroundings of Mubarak Road
Source: By researcher

Figure [5-10]: The Study Area-Mubarak Road
Source: By researcher

- **Location and components of Mubarak Road**

Mubarak Road is located in El-Sherouk City, Cairo-Egypt. The length of Mubarak road is around 8 Km and it divide El-Sherouk city into two half's as it shown in the above figure [5-10]. Mubarak Road is an arterial main road in El-Sherouk City because on the north side of Mubarak road there is Cairo-Ismalia Desert Road. The south side of Mubarak road there is Cairo-Suez Desert Road which connects El-Sherouk city to main destination which are Madinaty City and New Cairo as shown in figure [5-9]. Moreover, Mubarak road connects El-Sherouk sub roads together which makes it the most important road in El-Sherouk City. Mubarak Road is a two way road as shown in figure [5-10]. Mubarak road is a main street with two direction, each direction has three lanes and has a width of 7 meters. Sidewalks are exists on the right side of each direction to provide pedestrian facility. The width of sidewalks is 1 meter and height of 20cm in addition for a landscape strips that cuts the street into two directions with a width of 1m and height of 20cm as shown in figure [5-11]. Street bumps are existing in the two directions of the road with three bumps in each direction. The dimensions of these bumps are 20cm High, 60cm Width, 7m long as shown in figure [5-11], Circular shape. Lighting units are existing on the both sides of each direction with 35 meters between each lighting unit. The total number of lighting units is 456 lighting unit for each direction. Trees and shrubs are existing in the street Landscape strips**.** The case study will focus only on one direction only**.**

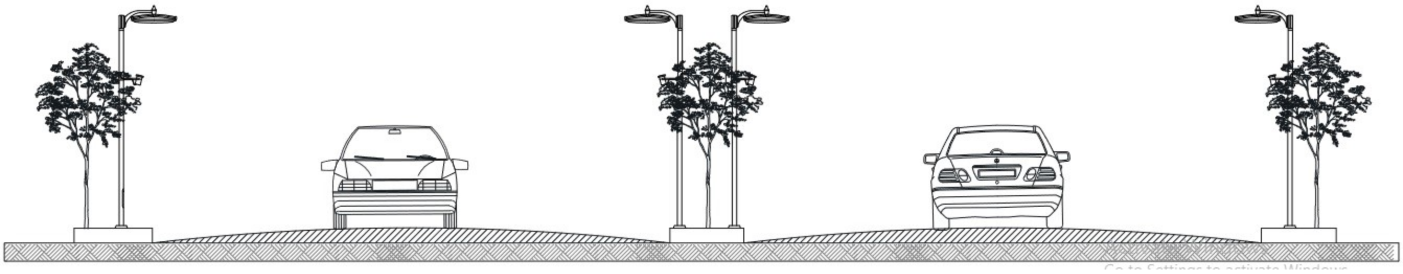


Figure [5-11]: A section View for -Mubarak Road
Source: By researcher

- **Climatic Conditions in El-Sherouk City**

El-Sherouk city is located at the northeast of Cairo and at the north of new Cairo. The climate in Egypt is considered as a semi desert climate. The summer is hot dry, and the winter is moderate with small amount of rainfall but with huge amount of humidity due to river valley's effect. Climatic condition in Egypt considers as a bi-seasonal climate with winter extends between November and March and summer lasts from May to September. The variations between the seasons are variations in daytime temperature and variations in wind speed and humidity. The figure [5-12] show the average temperatures in El-Sherouk City during the year.

Climate data for El Shorouk (altitude: 189m) [hide]													
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Average high °C (°F)	18.2 (64.8)	19.8 (67.6)	23.3 (73.9)	28 (82)	32.3 (90.1)	34.5 (94.1)	35 (95)	34.6 (94.3)	31.9 (89.4)	29.8 (85.6)	25 (77)	20.1 (68.2)	27.71 (81.83)
Daily mean °C (°F)	12.9 (55.2)	13.9 (57)	16.7 (62.1)	20.5 (68.9)	24.4 (75.9)	26.9 (80.4)	27.9 (82.2)	27.9 (82.2)	25.5 (77.9)	23.5 (74.3)	19.4 (66.9)	14.7 (58.5)	21.18 (70.12)
Average low °C (°F)	7.7 (45.9)	8.1 (46.6)	10.2 (50.4)	13 (55)	16.5 (61.7)	19.4 (66.9)	20.8 (69.4)	21.2 (70.2)	19.2 (66.6)	17.2 (63)	13.9 (57)	9.4 (48.9)	14.72 (58.47)
Average precipitation mm (inches)	6 (0.24)	4 (0.16)	4 (0.16)	2 (0.08)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1 (0.04)	4 (0.16)	5 (0.2)	26 (1.04)

Figure [5-12]: Climate data for El-Sherouk City
Source: Climate-Data.org

5.4.3. Data Collection (Observation and Documentation)

The data collected in this research was through site observations and data documentations for the selected road. Two types of data were collected in this research, data collection one and data collection two. The data collection one (Electricity Supply), it is focusing on the source and amount of electricity consumed in Mubarak road. While the data collection two (Traffic Density), is a site survey for calculating the road traffic density by calculating the number and type of vehicles (Cars, Buses, trucks) crossing the road in working days and in weekends.

- **Data collection one (Electricity Supply):**

The data collected in this part was targeting the source and amount of electricity consumption in Mubarak road such as number of lighting features, number of advertisement boards and the number of traffic controlling devices as shown in table [5-3].

Table [5-3]: Annual Electricity consumption in Mubarak Road

Type	Number of Units	Electricity Consumption (Per Hour)	Winter working hours	Summer working hours	Electricity Consumption in winter/ day	Electricity Consumption in summer/ day	Number of summer days	Number of winter days	Annual Electricity Consumption
Lighting Column	456	500 watts	5pm – 6am =13 h	7pm – 5am = 10 h	2964000 watts	2280000 watts	180 day	180 day	943920000
Advertisement Boards	4	750 watts	5pm – 6am =13 h	7pm – 5am = 10 h	39000 watts	30000 watts	180 day	180 day	12420000
Traffic controlling device	0	500 watts	5pm – 6am =13 h	7pm – 5am = 10 h	0	0	180 day	180 day	0
Total Annual Consumption									956340000 W

- **Data collection Two (Traffic Density):**

The data collected in this section illustrate the traffic density in Mubarak Road as well as it identify the types of vehicles crossing this road. The traffic density was calculated through site survey which took place on Saturday 11, Tuesday 14, Thursday 16 and Friday 17 February 2018, these four days were chosen to represent the traffic density in Mubarak Road on the working days and weekends, knowing that Friday is a formal weekend in Egypt were all the companies and facilities is considered this day as a day off. While, the second day off in Egypt is divided between Saturdays or Sunday, some companies and facilities considered Saturday as the second weekend while the others is using Sunday as a day off. The traffic density was calculated during four different hours which represent the rush hours, average traffic density and low traffic density hours. Knowing that the rush hours in Egypt is between 7:30am till 9:30 and between 2:30 till 4:30 with a total of 4 hours every day. Moreover, the average traffic density is between 9:30am till 2:30pm and between 4:30pm till 12:30am with a total of 13 hours every day. While, the low traffic density hours is between 12:30am till 7:30 am with a total of 7 hours every day.

Table [5-4] The Traffic density in Mubarak Road

Days/ Date		Time	Small vehicles (Cars)	Big vehicles (Bus, mini Bus, Micro Bus and trucks)	Average Number of Small vehicles in Rush hours/ day	Average Number of big vehicles in Rush hours/ day	Average Number of Small vehicles in normal & low density hours/ day	Average Number of big vehicles in normal & low density hours/ day	Average Number of small Vehicles/ day	Average Number of Big Vehicles/ day
In some companies this is a weekend while in others it is a working day	Saturday 11/11/2017	8:30-9:30 am	1050	598	((1050+ 920)/2) =985*4 =3940 vehicle	((598+680)/2)= 639*4 =2556 vehicle	(690*13)+ (48*7) = 9306	(58*13)+ (0*7) = 754	3940+9306 = 13246	2556+754 = 3310
		3:00-4:00 pm	920	680						
		8:30-9:30 pm	690	58						
		2:00-3:00 am	48	0						
Working day	Tuesday 14/11/2017	8:30-9:30 am	2250	1520	((2250+ 1980)/2) = 2115*4 =8460 vehicle	((1520+1005)/2) = 1262.5*4 =5050 vehicle	(1500*13)+ (73*7) = 20011	(195*13)+ (6*7) = 2577	8460+20011 = 28471	5050+ 2577 = 7627
		3:00-4:00 pm	1980	1005						
		8:30-9:30 pm	1500	195						
		2:00-3:00 am	73	6						
Working day (next day weekend)	Thursday 16/11/2017	8:30-9:30 am	2260	1507	((2260+ 870)/2) = 1565*4 =6260 vehicle	((1507+998)/2) = 1252.5*4 =5010 vehicle	(378*13)+ (101*7) = 5621	(66*13)+ (3*7) = 879	6260+ 5621 = 11881	5010+ 879 =5889
		3:00-4:00 pm	870	998						
		8:30-9:30 pm	378	66						
		2:00-3:00	101	3						

		am								
Weekend	Friday 17/11/2017	8:30-9:30 am	128	29	((128+210)/2) =169*4 =676 vehicle	((29+40)2) =34.5*4 =138 vehicle	(70*13)+ (21*7) =1057	(13*13)+ (7*7) = 218	676+ 1057= 1733	138+ 218=356
		3:00-4:00 pm	210	40						
		8:30-9:30 pm	70	13						
		2:00-3:00 am	21	7						

Table [5-3] calculate the Average Number of vehicles in Rush hours/ day by calculating the average number of cars that has been found in the site survey which was held between 8:30-9:30am and 4:00-5:00 pm, this hours represent the rush hours in Egyptian roads. The average number of cars has been multiplied by 4 which represent the rush hours in Egyptian roads. While, the average number of vehicles in normal and low density hours/ day was calculated by multiplying the number of vehicles in the hour between 8:30-9:30 pm which represent the normal traffic density/hour by 13 which represent the total number of normal traffic density in Egyptian roads/day. Moreover, the normal traffic density in Egyptian roads/day is added to the number of vehicles found in the hour between 2:00-3:00 am which represent the low traffic density in Egyptian roads/hour and multiplying it with 7 hours which is the average of low traffic density in Egyptian roads/day.

5.4.4. Equipment's

The equipment's used in this research are the carbon (Co_2) statistical model and SSSE software. The Co_2 statistical model were used to calculate the amount of carbon emissions produced from Mubarak Road the study area of this research. While SSSE software were used to calculate the amount of energy saved from using Smart-streetscape elements in Mubarak Road.

- **Carbon (Co_2) Emission Model**

Carbon emission model intend to calculate the level of carbon emission in Mubarak road the research study are. The research will calculate the carbon emission produced from Mubarak road in a winter day because in winter the electricity consumption is more than the summer day and the traffic density is higher because of the education period.

The carbon emission model calculating the carbon emissions produced in roads in term of Co_2 produced from electricity generation and Co_2 produced from vehicles. Using the following equations which was described before in chapter 4

$$E(kWh=day) = P(W) \times t(h/day)/1000(W/kW):$$

$$CEe(A, E, Fi) = AEFi,$$

The above equations calculate the emissions produced from the electricity consumption, while the below equations calculate the emissions produced from big and small vehicles.

$$CE_{vm}(g,d) = L\left(\sum_{j=1}^{n}[No.of\ \ (g_j)] \times C(r_{g_j}) + \sum_{j=1}^{m}[No.of\ \ (d_j)] \times C(r_{d_j})\right),$$

$$CE \ = \ CE_e(A,E,F_i) + CE_{vm}(g,d)$$

$$= \ AEF_i + L\left(\sum_{j=1}^{n}[No.of\ \ (g_j)] \times C(r_{g_j}) + \sum_{j=1}^{m}[No.of\ \ (d_j)] \times C(r_{d_j})\right), i = 1,2,...,5. \qquad (4)$$

- **SSSE Software**

SSSE software will be used to identify the type of Smart-Streetscape elements that could be used in Mubarak Road. A list of proposed SSSE elements will be provided from the software to the research. An analytical data will also presented for each Smart-Streetscape element used in the project. This analytical data will summarize the costs, area, energy, lifetime and annual cost of maintenances for each Smart-Streetscape element that can be used in the project.

A comparison will took place between the existing streetscape elements in Mubarak road and Smart-Streetscape elements. The comparison took place in three sections; these sections are Design elements, Energy consumption and carbon emission reduction. The results will be presented in the result section in the form of tables, figures and charts.

Smart-Streetscape elements was chosen depending on the site conditions. For example, the wind speed in Cairo is approximately 0.00km/d in most of the year seasons which means that the wind turbines will not be used in this case study. Small hydropower will also not be used in this case due to the lack of natural running water source in the study area. Moreover, Biomass and biogas will not been used in the study area due to the lack of vegetation and greenery.

➢ **<u>Softscape Elements</u>**

Smart-Streetscape elements can't be integrated with softscape elements because it is very hard to integrated technical devices such as renewable energy devices with living elements such as plant and shrubs. Softscape elements will not change in this research but this research will provide some guidelines for choosing softscape elements that can reduce the energy consumption.

- **Water Features**

The Smart-streetscape elements that integrated with water feature will not be used in this research and that due to the lack of natural water source. Although, the case study has one water fountain but producing energy from artificial water source will consume more energy than the energy generated as well as it's initial cost is very high. water feature will not be integrated in renewable energy devices in this case study.

- **Hardscape Elements**

SSSE software, presents a list of Smart-streetscape elements that can be used in Mubarak road as shown in figure [5-13]. Three Smart-streetscape elements where chosen randomly to be applies in the study area.

SSSE

PLEASE Select you need for your project

#	Streetscape Elements	RE Devices	Streetscape properties (Area)	Streetscape properties (Cost)	RE Properties (Area)	RE Properties (Energy)	RE properties (Cost)	Total cost	mim. Area	Energy / Day	Maintenance cost / Year	Life time/ Year
☐	Piezoelectric cells (Pavement)	Trails	0.0000	0.0000	10.0000	2.0000	1500.0000	2397.0000	10.0000	2.0000	20.0000	15
☑	Piezoelectric cells (Roads)	Road Paving	0.0000	0.0000	10.0000	16.0000	6500.0000	7397.0000	10.0000	16.0000	20.0000	15
☐	P.V	Trails	2.0000	417.0000	2.0000	3.6000	850.0000	2148.0000	2.0000	3.6000	85.0000	25
☐	Small Wind Turbines	Trails	12.0000	2500.0000	12.0000	4.5000	1000.0000	3660.0000	12.0000	4.5000	20.0000	20
☐	Piezoelectric cells (Pavement)	Path	0.0000	0.0000	10.0000	2.0000	1500.0000	2397.0000	10.0000	2.0000	20.0000	15
☐	Piezoelectric cells (Roads)	Path	0.0000	0.0000	10.0000	16.0000	6500.0000	7397.0000	10.0000	16.0000	20.0000	15
☐	P.V	Path	2.0000	30.0000	2.0000	3.6000	850.0000	1762.0000	2.0000	3.6000	85.0000	25
☐	Piezoelectric cells (Pavement)	Pavements	0.0000	0.0000	10.0000	2.0000	1500.0000	2397.0000	10.0000	2.0000	20.0000	15
☐	Piezoelectric cells (Roads)	Pavements	0.0000	0.0000	10.0000	16.0000	6500.0000	7397.0000	10.0000	16.0000	20.0000	15
☐	P.V	Pavements	2.0000	10.0000	2.0000	3.6000	850.0000	1742.0000	2.0000	3.6000	85.0000	25
☐	Piezoelectric cells (Pavement)	Footpath networks	0.0000	0.0000	10.0000	2.0000	1500.0000	2397.0000	10.0000	2.0000	20.0000	15
☐	Piezoelectric cells (Roads)	Footpath networks	0.0000	0.0000	10.0000	16.0000	6500.0000	7397.0000	10.0000	16.0000	20.0000	15
☐	P.V	Footpath networks	2.0000	50.0000	2.0000	3.6000	850.0000	1782.0000	2.0000	3.6000	85.0000	25
☐	Piezoelectric cells (Pavement)	Open Space	0.0000	0.0000	10.0000	2.0000	1500.0000	1500.0000	10.0000	2.0000	20.0000	15
☐	P.V	Open Space	2.0000	10.0000	2.0000	3.6000	850.0000	1742.0000	2.0000	3.6000	85.0000	25
☐	P.V	Wooded area	2.0000	60.0000	2.0000	3.6000	850.0000	1792.0000	2.0000	3.6000	85.0000	15
☐	P.V	Picnic area	2.0000	10.0000	2.0000	3.6000	850.0000	1742.0000	2.0000	3.6000	85.0000	25

Figure [5-13]: List of Smart-streetscape elements that can be used in Mubarak road
Source: SSSE Software

Figure [5-14], presents the chosen Smart-streetscape elements that will be used in Mubarak road. Piezoelectric cells roads integrated with Road paving; P.V cells integrated with lighting features and P.V cells integrated with bus shelters are the Smart-streetscape elements that will be used to generate energy in the study area.

SSSE

Total Cost= 58817$
Total Energy produced= 869.2

Streetscape Elements	RE Devices	Total cost	Area	Energy/ Hour	Maintenance/ year	Life Time/year
Road paving	Piezoelectric cells (R)	20711.000 Edit	28 Edit	16.0000 Edit	61.6$	15
Lighting Features	P.V. Cells	34500.000 Edit	230 Edit	3.6000 Edit	9890$	25
Bus Shelters	P.V. Cells	3606.000 Edit	4 Edit	3.6000 Edit	172$	25

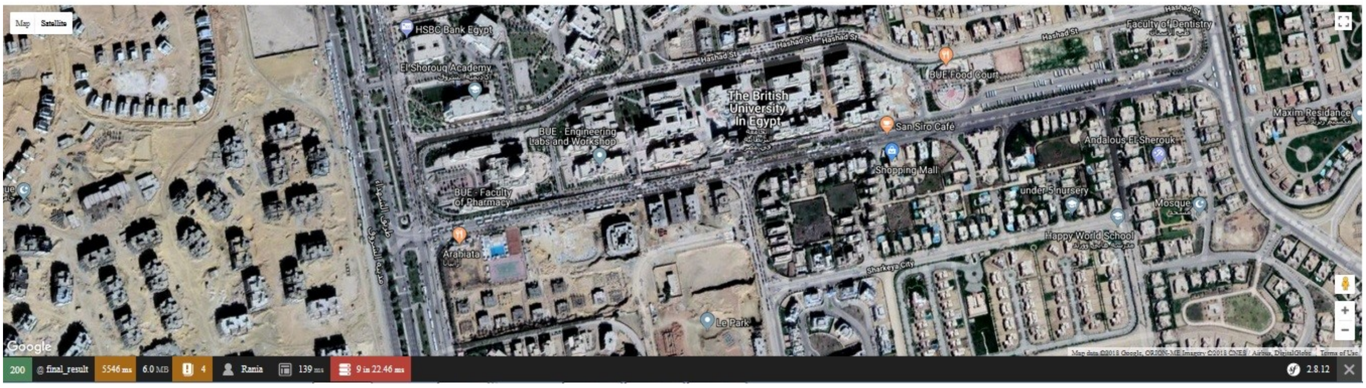


Figure [5-14]: Smart-streetscape elements in Mubarak Road
Source: SSSE software

The area of Smart-streetscape elements was calculated according to the site conditions, the research measured the area of hardscape elements (road length, area of bus shelter and number of lighting feature) which will be replaced by Smart-streetscape elements. This area was calculated and entered in SSSE software as shown in Figure [5-14]. Figure [4-31] presents the initial cost, total area needed, energy produced, lifetime, and annual maintenance fees of Smart-streetscape elements after modifying the area relative to the area of hardscape elements.

5.4.5. Procedures

The procedures of this research took place in four stages as shown in the below figure [5-15]. Figure [5-15] illustrated the work done in this research and it divide it in two four stages, the implementations of these four stages will be explained further in this section.

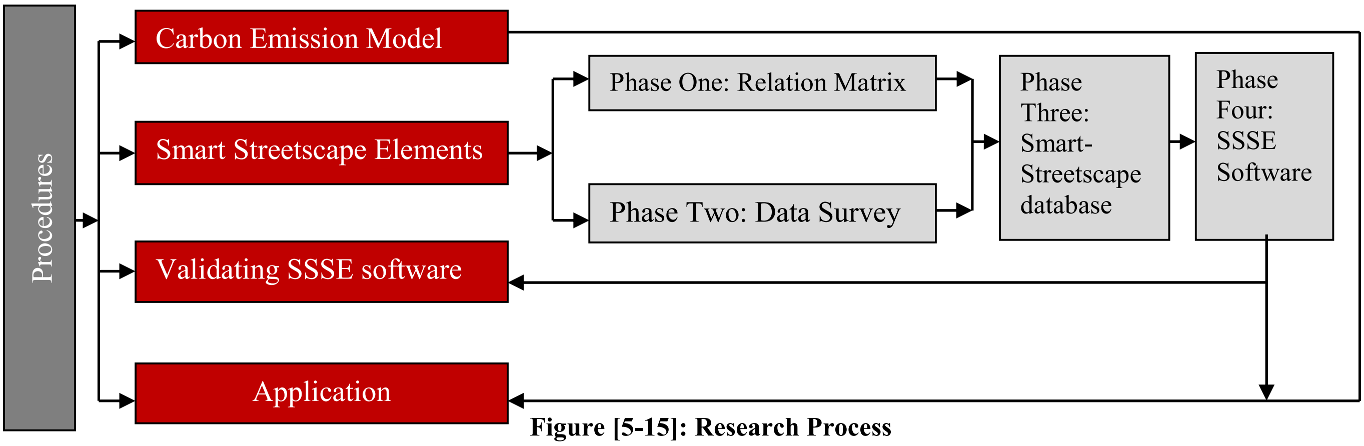


Figure [5-15]: Research Process

Source: By researcher

- **Stage One:** is a Carbon Emission Model, where the research designed a statistical model to measure the level of carbon emissions in a designed road in order to help the designers in modifying their design during the designing phase. Moreover, the model can measure the average level of carbon emissions produces from existing roads without using heavy and expensive equipment's. The model measures the carbon emissions relevant to the electricity consumed in the road and the traffic density.
- **Stage Two:** identifying and presenting Smart-streetscape elements. This stage identified Smart-streetscape elements in 4 consistence steps as shown in figure [5-15]. **Step one:** A relation matrix, the procedures in this step started by a wide search targeting projects and experiments in the last 30 years that implement renewable energy within the urban context. Depending on the data collected, a relation matrix was created, these relation matrix identified the streetscape elements that can be integrated by each RE device as it was explained before in chapter 4. **Step two:** Is a cross-section surveys, two Cross-Sectional survey was conducted to identify the properties of streetscape elements and renewable energy devices; the data was collected from interviews that took place with 15 managers from different pioneer companies that works in the field of streetscape and renewables. 25 meetings with the managers of these 15 companies took place between January 2017 and April 2017. Regarding the data collection in for renewables, 12 companies participated. Each company provided the research with a list of renewable energy devices that they work with and the properties of each devices. This data were collected and summarized. Some renewable energy devices are not used widely in Egypt and due to the lack of

information regarding these devices in Egyptian companies; an international advertising websites completed the missing information's. Regarding the streetscape elements, an interview took place with the head of "Curve Landscape Company" one of the most popular and well know company in the field of landscape and streetscapes in the Egyptian society. In the interview the head of the company answered almost the 38 questions regarding the properties of streetscape elements. Moreover, he provided the research with a price list for all streetscape elements that the company implement in different projects. **Step Three:** is the data analysis step. It took place to analyse the relations between the relation matrix and the data collected from the two Cross-Sectional surveys as presented before in table [4-4]. This database presents the properties of Smart-streetscape elements towards costs, area, energy produced, lifetime and annual cost of maintenances. **Step Four:** SSSE software, the database that was created in step three used to create a new software called "SSSE software", SSSE stand for Smart Street Scape Elements. This software was created to help the architects, urban designers and streetscape designers to use Smart-streetscape elements efficiently. The main purpose of SSSE software is to identify the most suitable Smart-streetscape elements that could be implement in a specific road. SSSE software will provide a list of Smart-streetscape elements to the designer and an analytical data will also be presented for each element to help the designer in choosing the most suitable elements. This analytical data will summarize the costs, area, energy, lifetime and annual cost of maintenances for each chosen Smart-streetscape element.

- **Stage Three:** validating SSSE software, the research validate SSSE software through a qualitative method as shown in figure [5-15]. 56 participant participated in this research, which took place in February 2018. The participant were asked to redesign a specific road and replace the streetscape elements with Smart-streetscape elements using the Smart-streetscape elements data at the begging. After that, the participants were asked to redesign the same road and replace streetscape elements with Smart-streetscape elements using SSSE software. Finally, a set of questions were given to the participants to measure and summarize there experience before and after using the software. The answers were collected and entered in a statistical analysis program "SPSS program" in order to know the opinion of the professionals about the proposed software.
- **Stage Four:** Application stage, the stage is applying the Carbon Emission Model and SSSE software on a study area [Mubarak road] as shown in figure [5-15]. A comparison has been made between the existing streetscape elements and Smart-streetscape elements. The comparison were made to test the research hypothesis by measuring the reduction of the carbon emissions and the production of energy. The results presented in form of tables, figures and charts.

5.4.6. Results

The results section of this research is divided into three parts: part one: calculating the carbon emission, were the research presents the existing amount of emissions produced from the study area using the Carbon Emission Model. Part two: applying Smart-streetscape elements on the study area, were the research measure the energy produced from Smart-streetscape elements and compare it with the road electricity consumption Part three: carbon emission reduction, were the research compare the level of carbon emissions before and after using Smart-streetscape elements.

- **Part one: Calculating the Carbon Emissions**

Carbon emission model intend to calculate the level of carbon emission in Mubarak road the research study are. The research will calculate the carbon emission produced from Mubarak road in a winter day because in winter the electricity consumption is more than the summer day and the traffic density is higher because of the education period.

The carbon emission model calculating the carbon emissions produced in roads in term of Co_2 produced from electricity generation and Co_2 produced from vehicles.

- **Co_2 produced from electricity generation**

Since the study area is located in El-Sherock city, therefore the source of power plant that supplies the city is natural gas. According to table [4-1], the average grams of CO_2 produced from generating one kWh of electricity or heat in power plants that operates using natural gas is 380 g/kWh. Therefore Fi=380 g/kWh.

The study calculated the electricity consumption in a winter day using the collected data in Table [5-3] and Equation (1) which was presented in chapter 4, section 4.2.1.

According to table [5-3], the average of electricity Consumption in a winter day E= (2280000+30000)/1000 kWh. Therefore, the daily CO_2 emission (CE) as a result of usage electricity consuming features

CEe (A, E, F5) = A E Fi =1 x 2310 (KWh) x 380 (CO2 g/kWh) =877800 g. = 21067200 g/h

- **Co2 produced from vehicles.**

The average carbon emission produced from vehicles was calculated as the following:

Two types of vehicles are considered, small vehicles such as BMW, Honda, Toyota…etc and big vehicles such as trucks and buses. According to the literature, the average fuel consumption rate for the small vehicles that depend on gasoline, r_g =40 mpg (mile per gallon), while the average fuel consumption rate for the big vehicles that depend on diesel, r_d =30 mpg. Then emitted grams of CO_2 per Km, C(rg) due to fuel consumption rate rg =40 is 163.838943054 g/km CO_2. While, Then emitted grams of CO_2 per Km, C(rd) due to fuel consumption rate rd =30 is 249.524827065 g/km CO_2. According to Table [5-4], the average number of small vehicles in a winter day is 13832.8 and the average number of big vehicles in a winter day is 4295.5. Therefore, the carbon emission as result of vehicles motion through highway with 8 Km is

$$CE_{vm}(g,d) = 8\,((13832.8)\,(163.838943054)+(4295.5)(249.524827065))= 2.67054\text{x}10^7\text{g}.$$

∴ The average carbon emission produced from Mubarak road in a winter day is 2.75832 x10^7g.

- **Part two: Applying Smart-streetscape Elements on the Study Area**

A comparison has been made between the energy consumption of Mubarak road and the energy produced from using Smart-streetscape elements in order to study the efficiency of Smart-streetscape elements.

The SSSE software revealed that four strips of piezoelectric cells installed in Mubarak road generates an average of 16 kWh/Car as shown in figure [5-14]. Table [5-5] revealed that using 4 strips of piezoelectric cells in Mubarak road produced an average of 8121456 kWh every day in the winter season.

Table [5-5]: Energy produced from 4 strips of Piezoelectric cells in Mubarak road

Days/ Date		Average Number of small Vehicles/ day	Average Number of Big Vehicles/ day	Average number of vehicles/ day	Energy produced from Piezoelectric road/ Day
semi weekend semi working day	Saturday 11/11/2017	3940+9306 = 13246	2556+754 = 3310	13246+3310= 16556	16556 * 16 = 264896 kWh
Working day	Tuesday 14/11/2017	8460+20011 = 28471	5050+ 2577 = 7627	28471+ 7627= 36098	36098 *16 = 577568 kWh/day
Working day (before weekend)	Thursday 16/11/2017	6260+ 5621 = 11881	5010+ 879 =5889	11881+ 5889= 17770	17770 *16 = 284320 kWh
Weekend	Friday 17/11/2017	676+ 1057= 1733	138+ 218=356	1733+356 = 2089	2089 * 16 = 33424 kWh
The Average daily energy produced from Piezoelectric road in Mubarak road					290052 kWh

Moreover, the study revealed that Smart-streetscape elements produce an average of 290138.4 kWh/day in the winter season, while the road consumed an average of 39039 kWh/day in the same season as shown in table [5-6].

Table [5-6]: Comparison between electricity consumption and production in Mubarak road

	Electricity consumption using Streetscape elements			Electricity production using Smart-Streetscape elements		
Type	**Number of Units**	**Electricity Consumption in Winter/ day**	**Electricity Consumption in Summer/ day**	**Lighting features/ P.V**	**Bus shelters/ P.V**	**Piezoelectric/ road Paving**
Lighting Column	456	2964000 watts = 38532 kWh	2280000 watts = 22800 kWh	3.6*12= 43.2 kWh/day	3.6*12= 43.2 kWh/day	290052 kWh/day
Advertisement Boards	4	39000 watts = 507 kWh	30000 watts = 300 kWh			
Traffic controlling device	0	0	0			
Total electricity consumption/ production		39039 kWh/day	23100 kWh/day	290138.4 kWh/day		

Therefore the results shows that using only three Smart-streetscape elements can produces an average 290138.4 kWh /day in the case of Mubarak road, which produced almost seven and half times more than the energy consumed in the road. On the other hand, it will increase the initial cost of the road by $ 58,817 only as shown in figure [5-14].

It was also notices that using the three Smart-streetscape elements will save to the city an average of 87,332L.E every day since that the 1 kW = 0.301 L.E as well as it will produce clean energy and help in creating sustainable city.

- **Part Three: Carbon Emission Reduction**

Mubarak road is located in El-Sherock city, which takes its electricity from Cairo power station. This power station use natural gas to generate energy and provided electricity the cities.

According to EIA (2016), generating electricity from power stations that operate using natural gas produces 1.22 pounds of CO_2 for every 1 kWh as shown in figure [5-16].

Fuel	Pounds of CO2 per million Btu	Heat rate (Btu per kWh)	Pounds of CO2 per kWh
Coal			
Bituminous	205.691	10,080	2.07
Subbituminous	214.289	10,080	2.16
Lignite	215.392	10,080	2.17
Natural gas	116.999	10,408	1.22
Distillate oil (No. 2)	161.290	10,156	1.64
Residual oil (No. 6)	173.702	10,156	1.76

Figure [5-16]: The amount of carbon emission produced from Natural Gas
Source (EIA, 2016)

Deepening on Figure [5-16], 1 kWh = 1.22 pounds of Co_2

∵1 b (pound) = 0.4536 Kg

∵The carbon emission produced from Natural gas= 1.22 b/kWh

∴ CO_2 =1.22×0.4536 = 0.5534 kg/kWh

∵ The energy consumed in Mubarak road is 39039 kWh/day

∴ The carbon emissions produced from lighting the road in winter season is 39039x0.5534 = 21604.1826 kg/kWh while in the summer season the Co2 emissions/day = 12783.54 kg/kWh as shown in table [5-7]

Table [5-7] The carbon emission produced from Mubarak Road

	Electricity consumption using Streetscape elements			Electricity production using Smart-Streetscape elements		
Type	**Number of Units**	**Electricity Consumption in Winter/ day**	**Electricity Consumption in Summer/ day**	**Lighting features/ P.V**	**Bus shelters/ P.V**	**Piezoelectric/ road Paving**
Lighting Column	456	2964000 watts = 38532 kWh	2280000 watts = 22800 kWh	3.6*12= 43.2 kWh/day	3.6*12= 43.2 kWh/day	290052 kWh/day
Advertisement Boards	4	39000 watts = 507 kWh	30000 watts = 300 kWh			
Traffic controlling device	0	0	0			
Total electricity consumption/ production		39039 kWh/day	23100 kWh/day	290138.4 kWh/day		
Daily carbon emission produced		39039 x 0.5534 =21604.1826 kg/kWh	23100 x 0.5534 = 12783.54 kg/kWh	0 kg/kWh		
Annual carbon emission produced		(21604.1826 x 180) + (12783.54 x 180) = 6189790.068 kg/kWh		0 kg/kWh		

According to the carbon emission model the average CO_2 emission produced from electrifying Mubarak road is 21067200g/h = 21067.2 kg/kWh while the total CO_2 emission produced from vehicles and electricity is 2.75832 x10^7g = 275832 kg/kWh.

CO_2 emission reduction for Short-term scenario:

For short-term scenario, the research intend to generate electricity using Smart-streetscape elements, which produced almost 0kg of carbon emission.

According to Table [5-7] and the carbon emession model the avaerge CO_2 emission produced from electrifying Mubarak road is 21067200g/h = 21067.2 kg/kWh. While, using three smart-streetscape elements produce almost 290138.4 kWh/day.

Using three Smart-streetscape elements in the study area will reduce daily an average of 290138.4 x 0.5534 =160562.59056 kg/kWh of CO_2 emissions and it will reduce annually 160562.59056 x 360 = **57802532.6016 kg/kWh.**

CO_2 emission reduction for Long-term scenario:
One of the biggest benefits from using Smart-streetscape elements is that it provide an infrastructure for electric vehicles. If every street generate its own electricity, it will be very easy to install electric spencer's in roads and streets, which is the main issue that stand in front of spreading electric vehicles especially in 3rd word countries.

5.5 DISCUSSION

Smart-Streetscape elements is a sustainable elements and it could be considered as the new generation of Streetscape elements, it is the product of integrating streetscape elements with renewable energy devices. Smart-Streetscape elements can be defined as sustainable elements that share the properties of streetscape elements and it generates clean & efficient energy from renewable energy devices. The main aim of this study is to reduce the roads carbon emissions using Smart-streetscape elements by presenting a short and long term scenario. The research investigates the effect of Smart-streetscape elements toward reducing the roads carbon emission in the short term scenario, by providing enough electricity to light the roads and public services using renewables devices which on the other had reduced the Co_2 emissions produced for generating electricity using fossil fuel to light these facilities. Moreover, the research discuss the possibility of generating enough energy to provide an infrastructure for electric vehicles which will reduce the co2 emissions on long term.
This chapter presents the theoretical and practical discussion, conclusions, general recommendations and future proposed research. The research discussion is divided into two main parts:

5.1.1 Discussion of the Graphical Abstract

The most important finding from this study is the significant impact of generating energy using Smart-streetscape elements and reduce the roads carbon emissions using this sustainable elements.

Streetscape elements are no longer considered a mere aesthetic component of the city but have become a part of the urban environment and this research proved its efficiency toward creating sustainable urban environment. The benefits of Smart-streetscape elements toward environmental and economic aspects has been proved in this research.

The research finding is consistent with the research hypothesis. The hypothesis of this research is that the carbon emissions produced in roads and transportation sectors is from electricity consumption and the heavy use of fossil fuels in vehicles and tucks, which can be reduced by integrating Streetscape elements with RE devices, Smart-Streetscape elements (SSSE) will be created, which will produce clean and efficient energy that can be used for lighting the neighbourhood's streets and decrease the energy taken from the government for public services in a short term strategy. But for long term strategy, it could be used to generate electricity for electric spencer that will be used to charge the electric vehicles. The short term strategy should decrease the carbon emissions produced from electricity while the long term strategy should decrease the carbon emissions produced from vehicles and trucks. The hypothesis has been proved in this research in 4 phases as shown in figure [5-17].

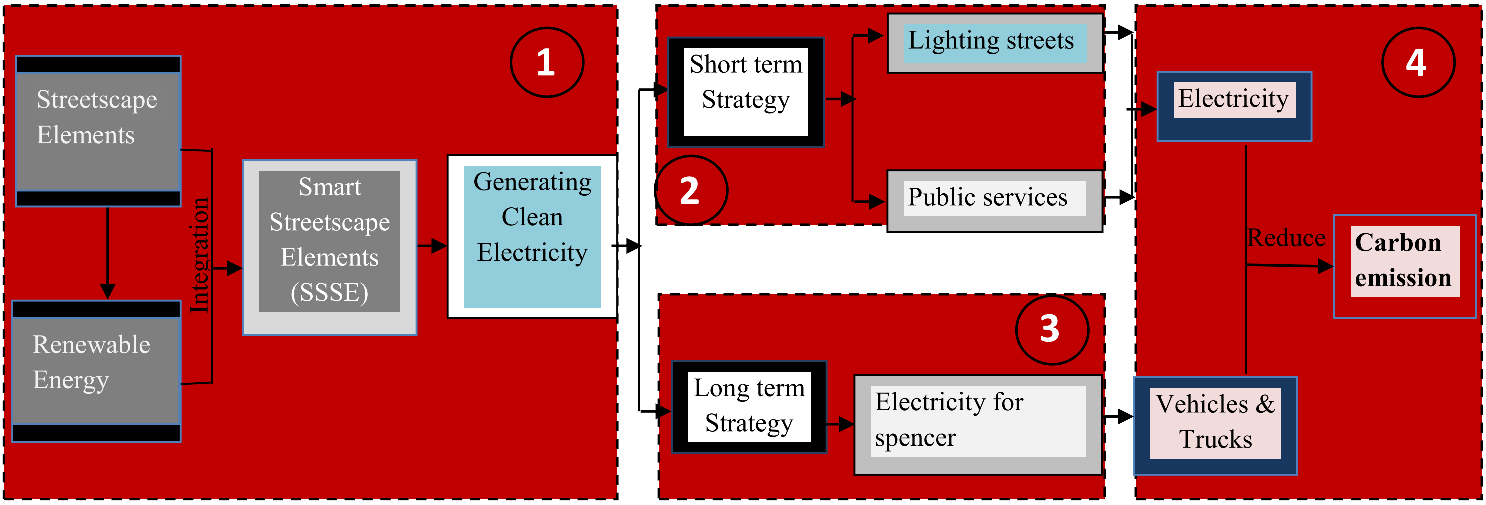


Figure [5-17]: Graphical abstract for the research framework
Source: By researcher

Phase 1, has been proved from Smart-streetscape database and SSSE software that Streetscape elements and renewable energy devices can be integrated and Smart-streetscape elements can be created.

Phase 2, has been proved that Smart-streetscape elements can affect the economic aspect of the project by producing clean energy from renewable devices and by reducing energy taken from the governments as it has been seen in this research case study in the results in "Part two: Applying Smart-streetscape Elements on the Study Area". The results reveled that using 3 Smart-streetscape elements will produce seven time and half more than the energy consumed in the study area. Therefore, if Smart-streetscape elements are used in all the city streets, this energy can be used in the short term to cover the energy consumed by the road and it can provide enough energy for the public services. Moreover, in the long term it can be used to provide electricity that will replace the fossil fuel to operate electric cars which will be consistent with phase 3.

Phase four, has been also proved in the theoretical part in chapter 2 and in the empirical part in the result section in “Part Three: Carbon Emission Reduction”. Moreover, Smart-streetscape elements affects the environmental aspect of the surrounding by generating energy with zero carbon emission, which will help in creating low carbon cities and create a clean and healthy environment.

The graphical abstract that is shown in figure [6-1] has discussed the possibility of creating sustainable urban project using Smart-streetscape elements by reducing the use of non-renewable energy and start replacing it with renewable energy devices through integrating it with the streetscape elements that will affect the economic and environmental state of a city. As it has been proved in this research that the use of Smart-streetscape elements is very useful and efficient through comparing the energy consumption of the study area (Mubarak road) with the energy produced from using Smart-streetscape elements, the comparison drawn has revealed that Smart-streetscape elements produced seven and half time more energy than the consumption of the study area and that can be an extra income for any sustainable urban city, if the city starts to sell this no stop energy production to the vehicles owners, the economic state of the city will be increase and the city atmosphere will be cleaner. Moreover, it will help in reducing the energy demand form the governments which will help with the developments of a major projects in the Third World Countries that can’t be established due to the energy problem facing these undeveloped countries.

Smart-streetscape elements share the benefit of streetscape elements and renewable energy device. It affect the social state by increase the quality of life in the city offering more job opportunities, developing the community and giving it its identity, they also help in making the neighbourhoods more liveable place; they give the families and children a place to express their feelings and an outdoor space to play and enjoy their time (Tognoli, 1987; Keane, 1991; Browne, 1992; Kuo et al., 1998; Kuo and Sullivan, 2001; Sherer, 2003; German-Chiari and Seeland, 2004; Tyrväinen et al., 2005; Abe et al., 2007; Priego and Canales, 2008; Hiloidhari and Baruah, 2011; Capik et al., 2012; Matek and Schmidt, 2013; Singh, 2015). Smart-streetscape elements affect the economic state by increasing the property values since that people prefer to buy a property in a sustainable city and it reduce the electricity bills in public facilities due to the usage of renewable energy (Seila and Anderson 1984; Wolsink, 1988; Wolsink, 1989; Tyrvainen, 1999; Tyrvainen and Miettinen, 2000;

Mallett 2007; Wolsink, 2007; Wüstenhagen et al., 2007; Matsuoka and Kaplan 2008; Priego and Canales, 2008; Toke et al., 2008; Van der Horst and Toke 2010; Warren and McFadyen 2010; Pasqualetti, 2011).

Smart-streetscape elements also effect the environment, it do not burn fossil fuels and directly produce GHG because it generate energy from renewables devices. Although, some CO_2 is still produced during the manufacture and construction of renewable energy devices in the projects (Bao & Fang, 2013). Smart-streetscape elements create clean and health environment and reduce the carbon emissions (Givoni, 1991; McPherson and Rowntree, 1993; O'Reilly, 1996; Shashua-Bar and Hoffman, 2000; Givon, et al., 2003; IHA, 2003; Sherer, 2003; Tyrväinen, et al, 2005; Attia, 2006; Yu and Hien, 2006; Takebayashi and Moriyama, 2009; WEC, 2010; Yuksel, 2010; Erdogdu, 2011; URL.1., 2011; Capik, et al., 2012; Bao & Fang, 2013).

5.6 LIMITATION OF THE STUDY

The research shows some limitation in SSSE software. This limitation is summarized as the following:

1. SSSE software is limited in calculating the energy produced from Energy-scape elements and how much SSSE elements costs but it doesn't provide a calculation for the life cycle assessment.
2. SSSE software is very limited in calculating the properties of Smart-streetscape elements and it doesn't calculate the amount of carbon emissions reduction.
3. SSSE software display only the layout of the site although if it can display the design and implement of Smart-streetscape elements, that will encourage more the users to use the software
4. The bubble diagram presented by SSSE software is very basic and it doesn't help much in designing Smart-streetscape elements.

5.7 CONCLUSION

Energy is a fundamental input for any economic development. Today economic activity depends overwhelmingly on fossil fuel such as oil, coal and natural gas, these are non-renewable sources and they are decreasing. Non-traditional power and energy resources will be a main issue in the future in the distinguished inhabitant's areas. According to the new trend in the growth of the inhabitant areas, taken into consideration the high ration of the residential activity in the consumption of energy, it was proved that renewable energy is going to be an urgent field and have been recommended strongly in the field of researches and production of its equipment's. Renewable energy sources are available and have been used for centuries. The main issue for using renewables is that it have higher costs than fossil fuels. The cost of renewable energy resources are attributable in part to the characteristics of the device used, the low net energy ratios, its availability and capital intensity. Research on developing this technology may reduce the cost but may not make renewable energy cost competitive with fossil fuel market price in the near future.

This research focused on the economic and environmental perspective for using renewable energy devices. It shows that Smart-streetscape elements can be used efficiently in any city but it shows also that Smart-streetscape elements increase the initial cost of the road due to the use of renewable energy devices. Moreover, Smart-streetscape elements can produce more energy than the road may consume. In this research it has been proved that the use of Smart-streetscape elements is very useful and efficient through comparing the energy consumed of Mubarak road with the energy produced from using Smart-streetscape elements, the comparison drawn has revealed that using only three Smart-streetscape elements produced seven and half time more energy than the road consumed. Using Smart-streetscape elements can provide an extra income for city and reduce the electricity bills and collecting money from selling this non-stop energy production to the vehicle owners. If the 3rd world countries encourage using Smart-streetscape elements in their roads, there cities will be energy self-sustain and will sell this non-stop energy production and get an extra income. Smart-streetscape elements will help in developing these undeveloped countries that are not developed due to the energy problem. The value of this research is that it introduces a new element called Smart-streetscape elements, that can be applied everywhere, and it helps in reducing the global environmental problems such as reducing the carbon emissions, ozone depletion and climatic changes.

5.8 FUTURE RESEARCH

The analysis of the scenarios made it possible to identify Smart-streetscape elements and to improve the urban context and future research orientations toward a better understanding of energy consumption and energy conservation and their impacts on different QOL aspects. The future research can elaborate different methods to enhance urban cities using Smart-streetscape elements and it can discover new assessments for Humana quality of life toward energy.

The future research agenda will necessarily include a focus on Smart-streetscape elements which converge the quality of life and sustainability, like studying how to manufacture Smart-streetscape elements and how to enhance the urban and road designers toward using Smart-streetscape elements and the preservation of sustainable development. Future research mush target a model that involve Smart-streetscape elements with carbon emissions reduction.

The research further more recommends the following research fields and research prospects:

- Life cycle cost for managing Smart-streetscape elements
- Creating carbon emission index for Smart-streetscape elements
- Computer aided design for calculating Co_2 emission before and after using Smart-streetscape elements

REFERENCES

1. Abdallah, L. and El-Shennawy, T. (2013). Reducing Carbon Dioxide Emissions from Electricity Sector Using Smart Electric Grid Applications. *Journal of Engineering,* 3, pp.1-8. Available at: https://www.hindawi.com/journals/je/2013/845051/ (Accessed 15 July 2019).

2. Abu-Jeries, A., Elkhayat, M., Mahmoud, M., & Al-Salaymeh, A. (2016). A Guide to Energy in Egypt and Jordan Current Situation and Future Potentials. *Friedrich-Ebert-Stiftung Jordan & Iraq*, pp. 1-184. Available at: https://library.fes.de/pdf-files/bueros/amman/12534.pdf (Accessed 15 July 2019).

3. Abolhosseini, S., Heshmati, A., & Altmann, J. (2017). A Review of Renewable Energy Supply and Energy Efficiency Technologies. Seoul National University. pp.1-36. Available at: http://ftp.iza.org/dp8145.pdf (Accessed 25 November 2019).

4. AEE. (2009). Wind power in Egipt – Egypt wind farm tender attracts 32 bids. Reve. Retrieved from: https://www.evwind.es/2009/08/27/wind-power-in-egipt-egypt-wind-farm-tender-attracts-32-bids/973 (Accessed 23 December 2019).

5. Akpınar, A. (2013). The contribution of hydropower in meeting electric energy needs: The case of Turkey. *Renewable Energy*, 15, pp.206-219. Available at: https://www.sciencedirect.com/science/article/pii/S0960148112006209 (Accessed 15 July 2019).

6. Akpınar, A. Kömürcü, M.I. Kankal, M. (2011) Development of hydropower energy in Turkey: the case of Çoruh river basin. *Renewable and Sustainable Energy Reviews*, 15, pp.1201-1209. Available at: https://www.sciencedirect.com/science/article/pii/S1364032110003412 (Accessed 15 July 2019).

7. Akpınar, A. Kömürcü, MI. Özölçer, IH. Senol, A. (2011) Total electricity and hydroelectric energy generation in Turkey: projection and comparison. *Energy Sources, Part B: Economics, Planning, and Policy*, 6(3), pp.252–262. Available at: https://www.tandfonline.com/doi/abs/10.1080/15567240802534219 (Accessed 15 July 2019).

8. Albiba.com. (2019) [0nline] Available at: <http://www.alibaba.com/productgs/517995220/solar_advertising_led_open_sign.html?s=p> (Accessed 4 May 2019).

9. Allardyce, S. (2011). Small Scale Wind Power; Case Study: North Walls Community School. *United Kingdom: University of Strathclyde Engineering,* pp.1-73 (thesis). Available at: http://www.esru.strath.ac.uk/Documents/MSc_2011/Allardyce.pdf (Accessed 25 August 2019).

10. Alliance Downtown (2006) 'Downtown streetscape design guidelines', M. Pegler (Ed.), Streetscape Design Guidelines the Public Realm, Streetscape Steering Committee, Chicago, pp.97–98. Available at: http://s3.amazonaws.com/downtowngr.org/general/Streetscape-Design-Guidelines-2006.pdf?mtime=20170517165939 (Accessed 10 September 2019).

11. Al Masry Al Youm. (2018, February 7). Egypt plans first hydropower plant in Middle East. Egypt Independent. Retrieved from: https://egyptindependent.com/egypt-plans-first-hydropower-plant-middle-east/ (Accessed 2 December 2019).

12. Altinbilek, HD. (2002) Hydropower development in Turkey. *International Journal on Hydropower and Dams,* 9, pp.61-65. Available at:

https://www.researchgate.net/publication/289627735_Hydropower_development_in_Turkey (Accessed 15 July 2019).

13. Andrews, R. (2016) A review of concentrated solar power (CSP) in Spain. *Energy Matters*. Available at: http://euanmearns.com/a-review-of-concentrated-solar-power-csp-in-spain/ (Accessed 3 August 2019).

14. Attia, S. and Wanas, O. (2012) The Database of Egyptian Building Envelopes (DEBE): A Database for Building Energy Simulations. SimBuild 2012, *5th National Conference of IBPSA. Madison, USA,* pp.1-8. Available at: https://orbi.uliege.be/bitstream/2268/167466/1/SB12_TS02a_4_Attia.pdf (Accessed 28 July 2019).

15. Avezov, R.R. Akhatov, J.S. and Avezova, N.R. (2011) A review on photovoltaic-thermal (PV-T) air and water collectors. *Applied Solar Energ*y, 47(3), p.169–83. Available at: https://link.springer.com/content/pdf/10.3103/S0003701X11030042.pdf (Accessed 28 July 2019).

16. Baig, H. Heasman, K.C. and Mallick, T.K. (2012) Non-uniform illumination in concentrating solar cells. *Renewable & Sustainable Energy Reviews,* 16(8), p.5890–5909. Available at: https://www.sciencedirect.com/science/article/pii/S1364032112004133 (Accessed 28 July 2019).

17. Bakıs, R. (2007) The current status and future opportunities of hydroelectricity. Energy Sources, Part B: *Economics, Planning, and Policy*, 2, pp.259–66. Available at: https://www.tandfonline.com/doi/full/10.1080/15567240500402958 (Accessed 28 July 2019).

18. Bakıs¸ R. (2005) Electricity generation from existing multipurpose dams in Turkey. *Energy Exploration and Exploitation,* 23, pp.495–516. Available at: https://journals.sagepub.com/doi/abs/10.1260/014459805776986911 (Accessed 28 July 2019).

19. Balaman, S.Y. and Selim, H. (2016) Sustainable design of renewable energy supply chains integrated with district heating systems: A fuzzy optimization approach. *Journal of Cleaner Production*, 133, pp.863–885. Available at: https://www.sciencedirect.com/science/article/pii/S0959652616306618 (Accessed 28 July 2019).

20. Barth, M. and Boriboonsomsin, K. (2009) Traffic Congestion and Greenhouse Gases. ACCESS Magazine, 1(35), pp.2-9. Available at: https://escholarship.org/uc/item/3vz7t3db (Accessed 28 July 2019).

21. Berkun, M. (2010) Environmental evaluation of Turkey's trans boundary rivers' hydropower systems. *Canadian Journal of Civil Engineering,* 37, pp.648–58. Available at: https://www.nrcresearchpress.com/doi/abs/10.1139/L10-003#.XT2VHugzbIU (Accessed 28 April 2019).

22. Biello, D. (2008) Scientific American. Solar Power Lightens Up with Thin-Film Technology. Available at: http://www.scientificamerican.com/article.cfm?id=solar-power-lightens-up-with-thin-film-cells (Accessed 28 September 2019).

23. Bilena, K. Ozyurta, O. Bakırcıa, K. Karslıb, S. Erdoganc, S. Yılmaza M. and Comaklı. O. (2008) Energy production, consumption, and environmental pollution for sustainable development: A case study in Turkey. *Renewable and Sustainable Energy Reviews*, 12, p.1529-

1561.Available at: https://www.sciencedirect.com/science/article/pii/S136403210700041X (Accessed 28 July 2019).

24. Binder, J. (2000) Small hydroelectric power plants: a most efficient contribution to renewable energy, Karntner Elektrizitats Aktiengesellschaft (KELAG). *Sixty International Summer School Solar Energy*. Applications—Sustainable Energy Issues, University of Klagenfurt, Klagenfurt/Carinthia, Austria, pp. 15

25. Bissada, D. (2019). Egypt - Renewable Energy. *International Trade Administration*. Retrieved from: https://www.export.gov/article?id=Egypt-Renewable-Energy (Last access 28 November 2019).

26. Boyle, G. (2012) Renewable energy: power for a sustainable future. *Oxford University Press*, UK, p.20-60. Available at: http://oro.open.ac.uk/43269/ (Accessed 28 July 2019).

27. BP. (2017). Statistical Review of World Energy. Available at: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (Accessed 2 December 2019).

28. Bradford, A., & Pappas, S. (2017, August 12). Effects of Global Warming. Live science. Retrieved from: https://www.livescience.com/37057-global-warming-effects.html (Accessed 12 December 2019).

29. Boriboonsomsin, K., & Matthew, B. (2009). Impacts of Road Grade on Fuel Consumption and Carbon Dioxide Emissions Evidenced by Use of Advanced Navigation Systems. The National Academic of Sciences. Retrieved from: https://trid.trb.org/view/880589 (Accessed 4 December 2019).

30. CDIAC, (2017). Oak Ridge National Laboratory. Carbon Dioxide Information Analysis Center. Available at: https://cdiac.ess-dive.lbl.gov/ (Accessed 2 December 2019).

31. Center for climate and energy solutions. (2017). Global emissions. World Resources Institute. Available at: https://www.c2es.org/content/international-emissions/ (Accessed 2 December 2019).

32. Geothermal energy. (2016) *British Geological Survey BGS*, Available at: http://www.bgs.ac.uk/research/energy/geothermal/ (Accessed 19 September 2019).
33. Butler, T. Lerch, D. and Wuerthner, G. (2012) *The energy reader: Overdevelopment and the Delusion of Endless Growth.* The Foundation for Deep Ecology in collaboration with Watershed Media and Post Carbon Institute. pp. 384 Available at: http://www.postcarbon.org/publications/energy-big-book/ (Accessed 28 July 2019).

34. Buffet, P. (1982) Hybrid thermal and photovoltaic concentration collector. In: Proceedings of EC contractors' meeting, *Photovoltaic power generation*, 3, p.251–256. Available at: https://link.springer.com/chapter/10.1007/978-94-009-7136-3_34 (Accessed 17 September 2019).

35. CAPMAS. (2013). Central Agency for Public Mobilization and Statistics. Retrieved from http://www.capmas.gov.eg/default.aspx

36. Cantú, H.T. (2011). Life-Cycle Cost Analysis for Offshore Wind Farms: Reliability and Maintenance. Sweden: Department of Wind Energy, Gotland University. Pp. 73

https://pdfs.semanticscholar.org/1f81/d9fb2bfb44d99354837f49ecc583508f3c61.pdf (Accessed 15 July 2019).

37. Capik, M. Osman, Y.A. and Cavusoglu, I. (2012) Hydropower for sustainable energy development in Turkey: The small hydropower case of the Eastern Black Sea Region. *Renewable and Sustainable Energy Reviews,* 16, pp.6160–6172. Available at: https://ideas.repec.org/a/eee/rensus/v16y2012i8p6160-6172.html (Accessed 28 July 2019).

38. Carrville District. (2004) CentreUrban design streetscape master plan study, in: Streetscape Design, Vaughan, Canada, 2004, p.87. Available at: file:///C:/Users/Rania/Downloads/A76403-3%20VMEP%20Affidavit%20Exhibit%208.1%20-%20A4Z3T6.pdf (Accessed 15 July 2019).

39. Cellura, M. Grippaldi, V. Lo-Brano, V. Longo, S. and Mistretta, M. (2011) Life cycle assessment of a solar PV/T concentrator system. *In: Proceedings of the life cycle management conference*, Italy, pp. 12. Available at: https://core.ac.uk/download/pdf/53272224.pdf (Accessed 15 July 2019).

40. Charalambous, P.G. Maidment, G.G. Kalogirou, S.A. and Yiakoumetti, K. (2007) Photovoltaic thermal (PV/T) collectors: a review. *Applied Thermal Engineering* 27, p.275–286. Available at: https://www.sciencedirect.com/science/article/pii/S1359431106002316 (Accessed 28 July 2019).

41. Chemisana, D. (2011) Building integrated concentrating photovoltaics: a review. Renewable & Sustainable Energy Reviews, 15(1), p.603–611. Available at: https://ideas.repec.org/a/eee/rensus/v15y2011i1p603-611.html (Accessed 28 July 2019).

42. Chow, T.T. (2010) A review on photovoltaic/thermal hybrid solar technology. *Applied Energy*, 87(2), p.365–379. Available at: https://www.sciencedirect.com/science/article/pii/S0306261909002761 (Accessed 28 July 2019).

43. City of Cheyenne. (2017) STREETSCAPE / URBAN DESIGN ELEMENTS. pp.1-33 Available at: https://www.cheyennecity.org/DocumentCenter/View/747/Streetscape-Handbook?bidId=, (Report). (Accessed 29 July 2019).

44. City of Milwaukee. (2011) Milwaukee Streetscape Guidelines, pp.1-96 Available at: https://city.milwaukee.gov/ImageLibrary/Groups/cityDCD/planning/plans/Streetscape/pdf/2011.05.09_Milw_Guidelines.pdf, (Accessed 28 August 2019).

45. City of Toronto. (2017) Streetscape Manual. Available at: <https://www1.toronto.ca/wps/portal/contentonly?vgnextoid=0e88036318061410VgnVCM10000071d60f89RCRD> (Accessed 22 October 2017).

46. City of Tshwane. (2015) Street Design Guiding Principles, Housing & City Planning and Environmental Management Development City Planning Division, Botswana. Available at: http://www.tshwane.gov.za/sites/residents/Services/OpenSpaceManagement/Pages/Streetscape.aspx (Accessed 17 September 2019).

47. Cotellessa, S. Sanford, W. and Hicks, W. (2010) Streetscape Design Guidelines, Falls Church, Virginia, 2010, p.39. Available at: <http://www.fallschurchva.gov/Content/Government/Departments/DevelopmentServices/NWashStreetscapeGuidelines.pd?cnlid=3177> (Accessed 20 June 2012).

48. Daghigh, R. Ruslan, M.H. and Sopian, K. (2011) Advances in liquid based photovoltaic/ thermal (PV/T) collectors. *Renewable & Sustainable Energy Reviews* 15(8), p.4156–4170. Available at: https://ideas.repec.org/a/eee/rensus/v15y2011i8p4156-4170.html (Accessed 10 September 2019).

49. Dagnall, S. Hill, J. and Pegg, D. (2000) Resource mapping and analysis of farm livestock manures assessing the opportunities for biomass-to-energy schemes. *Bioresource Technology,* 71, pp.225–234. Available at: https://www.cabdirect.org/cabdirect/abstract/19991913723 (Accessed 3 July 2019).

50. Daley, R.M. (2003) STREETSCAPE GUIDELINES: for the City of Chicago Streetscape and Urban Design Program. Chicago Department of Transportation, Bureau of Bridges and Transit, Commissioner, Miguel d'Escoto, pp.1-129 Available at: https://www.chicago.gov/dam/city/depts/cdot/Streetscape_Design_Guidelines.pdf, (Accessed 20 June 2012).

51. Demirbas, A. (2001) Biomass resource facilities and biomass conversion processing for fuels and chemicals. *Energy Convers Manage*, 42, pp.1357–1378. Available at: <http://www.fallschurchva.gov/Content/Government/Departments/DevelopmentServices/NWashStreetscapeGuidelines.pd?cnlid=3177> (Accessed 20 June 2012).

52. DOE (US Department of Energy). (2010) "The Smart Grid: an estimation of the energy and CO_2 benefits". January, pp.1-172. Available at: https://energyenvironment.pnnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf (Accessed 28 July 2019).

53. Dursun, B. and Gokcol, C. (2011) The role of hydroelectric power and contribution of small hydropower plants for sustainable development in Turkey. *Renewable Energy*, 36, pp.1227–1235. Available at: https://www.sciencedirect.com/science/article/pii/S0960148110004532 (Accessed 28 July 2019).

54. Edinger, R. and Kaul, S. (2000) Humankind's detour toward sustainability: past, present and future of renewable energies and electric power generations. *Renewable and Sustainable Energy Reviews* 4, pp.295–313. Available at: https://ideas.repec.org/a/eee/rensus/v4y2000i3p295-313.html (Accessed 28 July 2019).

55. EEAA. (2005). Air quality Monitoring Report. Ministry of Environment Egyptian Environmental Affairs Agency. Retrieved from: http://www.eeaa.gov.eg/en-us/topics/air/airquality/monitoringindustrialemissions.aspx (Accessed 3 September 2019).

56. EIA. (2017) How much carbon dioxide is produced per kilo watthour when generating electricity with fossil fuels?. U.S. Energy Information Administration. Available at: https://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11 (Accessed 3 May 2019).

57. EIA. (2018). Country Analysis Brief: Egypt. US. Energy Information Adminstration. Available at: https://www.eia.gov/beta/international/analysis.php?iso=EGY (Accessed 18 October 2019).

58. EIP Associates. (2006) Sustainable Streetscape Green & Livable Open Space. Valley Boulevard Neighborhoods Sustainability Plan, Los Angeles, pp.152–157. Available at: https://www.globalfueleconomy.org/media/461049/me-and-wa_gfei_egypt_report_draft.pdf, (Accessed 20 June 2012).

59. El-Dorghamy A. (2015) Fuel Economy and CO_2 Emissions of Light-Duty Vehicles in Egypt. Centre for Environment and Development in the Arab Region and Europe (CEDARE). pp.1-26. Available at: http://web.cedare.org/wp-content/uploads/cedareimages/gfei_morocco_report_feb08_final__english.pdf (Accessed 28 September 2019).

60. Elsobki, M., Wooders, P., & Sherif , Y. (2009). Clean Energy Investment in Developingt Countries: Wind Power in Egypt. International Institution for sustainable Development. IISD. pp. 1-54. Available at: https://www.iisd.org/pdf/2009/bali_2_copenhagen_egypt_wind.pdf (Accessed 10 October 2019).

61. ENGINEERING.com. (2016) ENGINEERING.com LIBRARY. Available at: http://www.engineering.com/SustainableEngineering/RenewableEnergyEngineering/SolarEnergyEngineering/Photovoltaics/tabid/3890/Default.aspx (Accessed 10 October 2016).

62. EPA. (2019). Acid Rain. United States Environmental Protection Agency. Retrieved from: https://www.epa.gov/acidrain/what-acid-rain (Accessed 10 October 2019).

63. Erdogdu, E. (2011) An analysis of Turkish hydropower policy. *Renewable and Sustainable Energy Reviews* 15, pp.689-696. Available at: https://www.globalfueleconomy.org/media/461049/me-and-wa_gfei_egypt_report_draft.pdf, (Accessed 20 June 2019).

64. Frank, L. (2010). STREETSCAPE DESIGN: PERCEPTIONS OF GOOD DESIGN AND DETERMINANTS OF SOCIAL INTERACTION. Master thesis in Waterloo, Ontario, Canada, pp.1-167. Available at: https://uwspace.uwaterloo.ca/bitstream/handle/10012/5280/Laura%20Frank%20Thesis%202010%20Streetscape%20Design%20Perceptions%20of%20Good%20Design%20and%20Determinants%20of%20Social%20Interaction.pdf?sequence=1. (Accessed 20 December 2012).

65. Frederick R. Steiner & Kent Butler. (2006) Planning and urban design standards. The American Planning Association, pp.1-448. Available at: http://www.engineersbench.com/phil/docs/books/The%20Feynman%20Lectures%20on%20Physics%20-%20Book%201.pdf, (Accessed 20 December 2012).

66. Fukahorin, K. and Kubota, Y. (2003) The role of design elements on the cost-effectiveness of streetscape improvement. *Landscape and Urban Planning,* 63(2), pp.75–91. Available at: https://www.sciencedirect.com/science/article/pii/S0169204602001809 (Accessed 20 November 2019).

67. GWEC, (2011). “Global wind report— annual market update 2010”. *Global Wind Energy Council.* pp. 1-72. Available at: https://www.tureb.com.tr/files/bilgi_bankasi/dunya_res_durumu/7.gwec_annual_market_update_2010.pdf, (Accessed 28 July 2019).

68. Hamed, M.M., et al., (2013). THE ARAB REPUBLIC OF EGYPT FOR BETTER OR FOR WORSE: AIR POLLUTION IN GREATER CAIRO. Sustainable development department Middle East and North Africa region. The World Bank. Pp. 11-140. Retrived from: http://documents.worldbank.org/curated/en/972321468021568180/pdf/730740ESW0P09700Final0April02202013.pdf (Accessed 23 December 2019).

69. Hasan, M.A. and Sumathy, K. (2010) Photovoltaic thermal module concepts and their performance analysis: a review. *Renewable & Sustainable Energy Reviews*, 14 (7), p.1845–59.

Available at: https://www.sciencedirect.com/science/article/pii/S1364032110000663 (Accessed 10 October 2019).

70. Hassan, I. (1999). Air Pollution in Egypt. Environmental Education and Information, The University of Salford in association with the Tidy Britain Group, 18(1): 67-78.

71. Hill, D. Agarwal, A. and Tong, N. (2014) Assessment of Piezoelectric Materials for Roadway Energy Harvesting "Cost of Energy and Demonstration Roadmap". *California: DNV KEMA Energy & Sustainability*. pp.1-93. Available at: http://www.energy.ca.gov/2013publications/CEC-500-2013-007/CEC-500-2013-007.pdf, (book) (Accessed 28 July 2019).

72. City of Tshwane. (2007). STREETSCAPE DESIGN GUIDELINES. Housing, City Planning and Environmental Management Department City Planning Division – Streetscape Management Section. pp.1-75. Available at: http://www.gtkp.com/assets/uploads/20091129-215719-7868-Streetscape_Design_Guidelines%20SA.pdf, (Accessed 28 July 2019).

73. Ibrahim, A. Othman, M.Y. Ruslan, M.H. Mat, S. and Sopian, K. (2011) Recent advances in flat plate photovoltaic/thermal (PV/T) solar collectors. *Renewable & Sustainable Energy Reviews* 15(1), pp.352–365. Available at: https://www.sciencedirect.com/science/article/pii/S1364032110003114. (Accessed 28 July 2019).

74. IEA. (2004). Electricity Information 2004. Paris, France. *International Energy Agency.* Retrieved from: https://www.iea.org/countries/France/. (Accessed 25 June 2019).

75. IEA. (2018). Global Energy & CO2 Status Report. *International Energy Agency*. Retrieved from: https://www.iea.org/geco/emissions/ (Accessed 25 November 2019).

76. IRENA. (2018). Renewable Energy Outlook in Egypt. International Renewable Energy Agency. Abu Dhabi.pp. 1-8. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Oct/IRENA_Outlook_Egypt_2018_En_summary.pdf?la=en&hash=58DBAA614BE0675F66D3B4A2AC68833FF78700A0 (Accessed 28 July 2019).

77. Jahankhani, H. Hosseinian-Far, A. (2011) Efficiency Analysis of the Photovoltaic Systems for Carbon Footprint Reduction (Case Study: University of East London). 1st World Sustainability Forum. Basel, Switzerland. p1-7. Available at: https://sciforum.net/manuscripts/589/original.pdf. (Accessed 28 July 2019).

78. Janet, L.S. and Lisa, M. (2010) Prospects of the Renewable Energy Sector in Egypt Focus on Photovoltaic and Wind Energy. Egyptian-German Private Sector Development Programme. Cairo, Egypt.

79. Jennings, A. (2012) Streetscape Rain Garden Design Principles, Clearwater, Australia, pp. 1 Available at: https://www.clearwatervic.com.au/user-data/resource-files/A3-Raingarden-Quick-Reference-Guide_0.pdf (Accessed 1 July 2019).

80. Kandilli, C. (2013) Performance analysis of a novel concentrating photovoltaic combined system. *Energy Conversion and Management*, 67, p.186–196. Available at: http://isiarticles.com/bundles/Article/pre/pdf/28081.pdf (Accessed 28 July 2017).

81. Kapur, T. Kandpal, T.C. and Garg, H.P. (1998) Electricity generation from rice husk in Indian rice mills: potential and financial viability. *Biomass Bioenergy*, 14, pp.573–583. Available at:

https://www.sciencedirect.com/science/article/pii/0961953495001166. (Accessed 28 July 2019).

82. Kaygusuz, K. (1999) Electricity generation: a case study in Turkey. *Energy Sources*, 21, pp.275–290. Available at: https://www.tandfonline.com/doi/abs/10.1080/00908319950014894. (Accessed 30 July 2019).

83. Kaygusuz, K. (2004) Hydropower and the world's energy future. *Energy Sources*, 26, pp.215-224. Available at: https://www.tandfonline.com/doi/pdf/10.1080/00908310490256572. (Accessed 30 July 2019).

84. Knies, G., Mölle, U. and Straub, M. (2009) Clean power from deserts: the Desertec concept for energy, water and climate security. *DESERTEC Foundation*, pp.1-34 Available at http://www.chemtrailsgeelong.com/uploads/DESERTEC.pdf (Accessed 07 June 2019).

85. KNOEMA. (2018). *Egypt - CO2 emissions*. Retrieved from World Data Atlas: https://knoema.com/atlas/Egypt/CO2-emissions (Accessed 9 November 2019).

86. Kost, C. Mayer, J. Thomsen, J. Hartmann, N. Senkpie, C. Philipps, L. and Schlegl, T. (2013). Levelized Cost of Electricity *Renewable Energy Technologies. Fraunhofer Institut for Solar Energy Systems ise. Germany*. p.1-50 Available at: https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/Fraunhofer-ISE_LCOE_Renewable_Energy_technologies.pdf (Accessed 15 July 2019).

87. Krukanont, P. and Prasertsanb, S. (2004) Geographical distribution of biomass and potential sites of rubber wood fired power plants in Southern Thailand. *Biomass Bioenergy*, 26, pp.47–59. Available at: https://www.deepdyve.com/lp/elsevier/geographical-distribution-of-biomass-and-potential-sites-of-rubber-lmloPVNuUJ?impressionId=5d396ec7b41a2&i_medium=docview&i_campaign=recommendations&i_source=recommendations (Accessed 30 July 2019).

88. Kumar, R. and Rosen, M.A. (2011) A critical review of photovoltaic-thermal solar collectors for air heating. *Applied Energy,* 88(11), p.3603–3614. Available at: https://www.sciencedirect.com/science/article/pii/S0306261911002790 (Accessed 30 July 2019).

89. Li, M. Li, G.L. Ji, X. Yin, F. and Xu, L. (2011) The performance analysis of the trough concentrating solar photovoltaic/thermal system. *Energy Conversion and Management,* 52(6), p.2378–2383. Available at: https://www.sciencedirect.com/science/article/pii/S0196890411000422?via%3Dihub (Accessed 30 July 2019).

90. Lins, C., Williamson, L.E., Leitner, S., Teske, S., 2014. 10 YEARS OF 01 RENEWABLE ENERGY PROGRESS. (REN21) Renewable energy policy network for the 21 century. pp. 1-48. Available at: http://www.ren21.net/Portals/0/documents/activities/Topical%20Reports/REN21_10yr.pdf (Accessed 30 July 2019).

91. Loeb, A.P., & Nasralla, M.M. (2001). Review and Assessment of Air Quality Standards, Egyptian Environmental Law 4/1994. Egyptian Environmental Policy Program. Environmental Policy & Institutional Strengthening Indefinite Quantity Contract (EPIQ). pp.1-32. Retrieved from: file:///C:/Users/Rania/Downloads/054%20Air%20Standards%20Review-LN.pdf (Accessed 30 September 2019).

92. Los Angeles design guidelines. (2002) Architecture resources group Historic down town Los Angeles design guidelines, in: Architecture Resources Group. Streetscape Design Guidelines, *Architecture Resources Group, Los Angeles,* pp.144. Available at: https://www.ise.fraunhofer.de/content/dam/ise/en/documents/publications/studies/Fraunhofer-ISE_LCOE_Renewable_Energy_technologies.pdf (Accessed 15 July 2019).

93. Mao, G. Wang, S. Teng, Q. Zuo, J. Tan, X. Wang, H. and Liu, Z. (2017) The sustainable future of hydropower: A critical analysis of cooling units via the Theory of Inventive Problem Solving and Life Cycle Assessment methods. *Journal of Cleaner Production,* 142, pp.2446–2453. Available at: https://www.infona.pl/resource/bwmeta1.element.elsevier-4a7ba8c8-f2b0-3384-9503-84a239eaf5ea (Accessed 30 July 2019).

94. Matek, B. and Schmidt, B. (2013) The Values of Geothermal Energy: A Discussion of the Benefits Geothermal Power Provides to the Future U.S. Power System. *Geothermal Energy Association*. Washington DC, USA. pp 19. Available http://geo-energy.org/reports/Values%20of%20Geothermal%20Energy%20Draft%20Final.pdf (Accessed 30 July 2019).

95. Mazria, E. (2019). The 2030 Challenge. Architecture 2030. Retrieved from: https://architecture2030.org/2030_challenges/2030-challenge/ (Accessed 30 July 2019).

96. Mohajan, H. (2018). Acid Rain is a Local Environment Pollution but Global Concern . Munich Personal RePEc Archive. pp. 1-10

97. Mortensen, N.G., Said, U.S. and Badger, J. (2006) “Wind atlas for Egypt,” in Proceedings of the 3rd Middle East—North Africa Renewable Energy Conference (MENAREC ’06), Cairo, Egypt. p. 13 Available at: https://orbit.dtu.dk/ws/files/52612776/Wind_Atlas_for_Egypt_presentation.pdf (Accessed 30 July 2019).

98. Moussa, R.R. (2017) The Creation 0f Sustainable Neighborhoods Using Smart-Streetscape Elements (SSSE). The 1st international conference on towards a better quality of life. El GOUNA, Red Sea Region – EGYPT. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3163427 (Accessed 6 January 2019).

99. Muhammad, M. S.S. (2014). Opportunities of new and renewable energy in Egypt and horizons of future development. *Faculty of Urban and Regional Planning, Cairo University*. pp. 2-8. Retrivied from: https://scholar.cu.edu.eg/?q=m_salem/files/08_opportunities_of_new_and_renewable_energy_in_egypt_and_horizons_of_future_development_0.pdf (Accessed 30 October 2019).

100. Muneer, T. Maubleu, S. and Asif, M. (2006) Prospects of solar water heating for textile industry in Pakistan. *Renewable & Sustainable Energy Reviews*, 10, pp.1–23. https://www.sciencedirect.com/science/article/pii/S1364032104000930 (Accessed 30 July 2019).

101. MUTCD (The Manual on Uniform Traffic Control Devices) (2019) Manual Uniform Traffic Control Devices for Streets and Highways. U.S. Department of Transportation, Federal Highway Administration. Retrieved from: https://mutcd.fhwa.dot.gov/ (Accessed 30 November 2019).

102. Nasralla, M. M. (2001) GREATER CAIRO AIR QUALITY PROFILE. U.S. Agency for International Development, Cairo, and Egyptian Environmental Affairs Agency. Pp 71. Available at: file:///C:/Users/Rania/Downloads/034%20CairoAirProfile-Nasrala.pdf (Accessed 30 July 2019).

103. Nautiyal, H. Singal, S.K. and Sharma, A. (2011) Small hydropower for sustainable energy development in India. *Renewable and Sustainable Energy Reviews* 15, pp.2021–2027. Available at: https://www.sciencedirect.com/science/article/pii/S1364032111000219 (Accessed 30 July 2019).

104. NREA. (2018) New & Renewable Energy Authority – Annual Report 2018. *Ministry of Electricity & Renewable Energy, Arab Republic of Egypt*. pp.1-32. Retrieved from: http://nrea.gov.eg/Content/reports/Englishv2%20AnnualReport.pdf (Accessed 15 December 2019).

105. Otak Inc. (2007) Streetscape Urban Design Elements, City of Cheyenne, Cheyenne, pp.2–14. Available at: <http://www.otak.com/portfolio/landscape-architecture/cheyenne-streetscape-urbandesign-handbook/> (Accessed 19 July 2018).

106. Ozturk, M. Bezir, N.C. and Ozek, N. (2009). Hydropower water and renewable energy in Turkey: sources and policy. *Renewable and Sustainable Energy Reviews,* 13, pp.605-615. Available at: https://ideas.repec.org/a/eee/rensus/v13y2009i3p605-615.html (Accessed 30 July 2019).

107. Panwara, N.L. Kaushikb, S.C. Kotharia, S. (2011) Role of renewable energy sources in environmental protection: a review. *Renewable and Sustainable Energy Reviews*, 15, pp.1513–1524. Available at: https://www.sciencedirect.com/science/article/pii/S1364032110004065 (Accessed 30 July 2019).

108. PCB PIEZOTRONICS. (2016). Introduction to Piezoelectric Force Sensors. Available at: http://www.pcb.com/Resources/Technical-Information/Tech_Force (Accessed 7 July 2019).

109. Pérez-Higueras, P. Muñoz, E. Almonacid, G. and Vidal, P.G. (2011) High concentrator photovoltaics efficiencies: present status and forecast. *Renewable & Sustainable Energy Reviews*, 15(4), p.1810–1815. Available at: https://www.sciencedirect.com/science/article/pii/S1364032110004156 (Accessed 30 July 2019).

110. Permentier, K., Vercammen, S., Soetaert, S., & Schellemans, C. (2017, April 4). Carbon dioxide poisoning: a literature review of an often forgotten cause of intoxication in the emergency department. *International Journal of Emergancy Medicine*, 10(14), 1-4. Retrieved from: doi: 10.1186/s12245-017-0142-y. [Last access: 10 December 2019]

111. Puglia, G. (2013) Life cycle cost analysis on wind turbines. *Gothenburg, Sweden: Department of Energy and Environment, Division of Electric Power Engineering, Chalmers University of Technology. Gothenburg, Sweden.* pp.1-73. Available at: http://publications.lib.chalmers.se/records/fulltext/179861/179861.pdf, (Accessed 15 November 2018).

112. Purohit, P. (2009) Economic potential of biomass gasification projects under clean development mechanism in India. *Journal of Cleaner Production,* 17, pp.181–193. Available at https://www.cabdirect.org/cabdirect/abstract/20093024728 (Accessed 30 July 2019).

113. Quaia S. Lughi V. Giacalone M. and Vinzi G. (2012) Technical-economic evaluation of a combined heat and power solar (CHAPS) generator based on concentrated photovoltaics. International symposium on power electronics, electrical drives, automation and motion, Sorrento, Italy, pp.1130–1135. Available at: https://www.researchgate.net/publication/261155447_Technical-economic_evaluation_of_a_Combined_Heat_And_Power_Solar_CHAPS_generator_based_on_concentrated_photovoltaics (Accessed 30 July 2019).

114. Quej, V.H. Almorox, J. Ibrakhimov, M. and Saito, L. (2017) Estimating daily global solar radiation by day of the year in six cities located in the Yucat an Peninsula, Mexico. Journal of Cleaner Production, 141, pp.75–82. Available at: https://www.tib.eu/en/search/id/tema%3ATEMA20161106532/Estimating-daily-global-solar-radiation-by-day/ (Accessed 30 July 2019).

115. Rahman, T. Sakir, S.R.and Onna, S.D. (2012) Design of an efficient energy harvester from ambient vibration. Department of Electrical and Electronic Engineering, (EEE) BRAC University, Dhaka, Bangladesh. pp.1-77. Available at: http://dspace.bracu.ac.bd/xmlui/bitstream/handle/10361/1832/Design%20of%20an%20efficient%20energy%20harvester.pdf?sequence=1&isAllowed=y, (Accessed 8 July 2019).

116. Rashad, S.M., & Ismail, M.A. (2000). Environmental-impact assessment of hydro-power in Egypt. *Applied Energy*, 65(1-4), 285-302. Available at: https://doi.org/10.1016/S0306-2619(99)00068-9 (Accessed 30 July 2019).

117. Rehan, R.M. (2013) Sustainable streetscape as an effective tool in sustainable urban design. *HBRC Journal,* 9, pp.173-186. Available at: https://reader.elsevier.com/reader/sd/pii/S1687404813000102?token=BFC62937CA0E0331E48484ADB73ED41DE3EEEA67105B1AE169C7506ADA58DA67C8271A54D165C05617817278E840B8DC (Accessed 8 July 2019).

118. Richard, M. (2003). Streetscape Guidelines for the City of Chicago Streetscape and Urban Design Program, Chicago Department of Transportation, Chicago, USA. pp. 3–17. Available at: https://www.chicago.gov/dam/city/depts/cdot/Streetscape_Design_Guidelines.pdf, (Accessed 30 July 2019).

119. Ritchie, H., & Roser, M. (2017). CO_2 and Greenhouse Gas Emissions. *Our World in Data*. Retrieved from: https://ourworldindata.org/co2-and-other-greenhouse-gas-emissions (Accessed 30 July 2019).

120. Rolland, S. and Auzane, B. (2012) The potential of small and medium wind energy in developing countries. Belgium: Alliance for Rural Electrification, Renewable Energy House. pp. 12 Available at: https://www.ruralelec.org/sites/default/files/are_small_wind_position_paper.pdf (Accessed 8 July 2019).

121. RRM (2007) San Luis Obispo, CAStrategic plan, in: Commons C. Urban Design and Streetscape Plan, RRM Design Group, Camarillo, pp.61–63. Available at: <http://www.ci.camarillo.ca.us/docs/60045.pdf> (Accessed 8 June 2018).

122. Sawin, J. L., & Mastny, L. (2010). Prospects of the Renewable energy sector in Egypt–focus on photovoltaic and wind energy. Egyptian-German Private Sector Development Programme.

123. Sethi, P. (2015) California Energy Commission. Available at: http://www.energy.ca.gov/biomass/ (Accessed 17 October 2016).

124. Sharaf, O.Z. and Orhan, M.F. (2015) Concentrated photovoltaic thermal (CPVT) solar collector systems: Part II – Implemented systems, performance assessment, and future directions. *Renewable and Sustainable Energy Reviews,* 50, p.1500–1565. Available at: https://www.sciencedirect.com/science/article/pii/S1364032114006753 (Accessed 30 July 2019).

125. Sherwani, A. Usmani, A. and Varun, J. (2010) Life cycle assessment of solar PV based electricity generation systems. *Renewable and Sustainable Energy Reviews*, p.540–544. Available at: https://ideas.repec.org/a/eee/rensus/v14y2010i1p540-544.html (Accessed 30 July 2019).

126. Singh, B. and Othman. M.Y. (2009) A review on photovoltaic thermal collectors. *Journal of Renewable and Sustainable Energy,* 1(6), pp. 14 Available at: https://ideas.repec.org/a/eee/rensus/v42y2015icp286-297.html (Accessed 30 July 2019).

127. Singh, J. (2015) Overview of electric power potential of surplus agricultural biomass from economic, social, environmental and technical perspective—A case study of Punjab. *Renewable and Sustainable Energy Reviews,* 42, pp.286–297.

128. Sodano, H. and Inman, D. (2004) Estimation of Electric Charge output for Piezoelectric Energy Harvesting. *Strain Journal*, pp.49-58. Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.546.5005&rep=rep1&type=pdf (Accessed 30 July 2019).

129. Somashekhar, H.I. Dasappa, S. and Ravindranath, N.H. (2000) Rural bioenergy centres based on biomass gasifiers for decentralized power generation: case study of two villages in southern India. *Energy Sustainable Dev,* 4(3), pp.55–63. Available at: https://www.sciencedirect.com/science/article/pii/S0973082608602537 (Accessed 30 July 2019).

130. Streetscape elements. (2001) Rockville Town Centre: pp. Available at: http://www.rockvillemd.gov/documentcenter/view/937. (Accessed 28 March 2017).

131. Tetra. (2009) TechGreen Streetscapes Study, HOPE Community Development Area, Washington, pp.3–25. Available at: <http://epa.gov/brownfields/sustain_plts/reports/Streetscapes_Final_7_31_09.pdf> (Accessed 2 June 2018).

132. Tiwari, A. Ahmad, M. Tripathi, A. and Mishra, A. (2012) Energy Harvesting Through Piezoelectric Cells for Commercial Use. *VSRD International Journal of Electrical, Electronics and Communication Engineering*, 1, pp.404-411.

133. Tyagi, V.V. Kaushik, S.C. and Tyagi, S.K. (2012) Advancement in solar photovoltaic thermal (PV/T) hybrid collector technology. *Renewable and Sustainable Energy Reviews*, 16(3), p.1383–1398.

134. UCSUSA. (2017). Why Does CO_2 get Most of the Attention When There are so Many Other Heat-Trapping Gases? Union of Concerned Scientists. Retrieved from: https://www.ucsusa.org/resources/why-does-co2-get-more-attention-other-gases (Accessed 15 November 2019).

135. Umeda, M. Nakamura, K. and Ueha, S. (1997) Energy Storage Characteristics of a Piezo-Generator using Impact Induced Vibration. *Japanese Journal of Applied Physics*, 36 (1) 5B, pp.3146-3151.

136. UNDP. (2018). Climate Change Adaptation. United Nations Development Program. Retrieved from: https://www.adaptation-undp.org/explore/northern-africa/egypt (Accessed 7 July 2019).

137. UNFCCC, (2010) Egypt Second National Communication under the United Nations Framework Convention on Climate Change, Egypt. Egyptian Environmental Affairs Agency (EEAA). pp. 1-137 Available at: https://unfccc.int/sites/default/files/resource/Egypt-SNC%20CD.pdf (Accessed 15 December 2019).

138. Upadhyay, G. Sharma, R.D. Girdhar, J.B.S. Garg, B.M.L. and Mohan, S. (2005) Biomass power potential in India—an overview. In: Pathak BS, Srivastava NSL, editors. Biomass based decentralized power generation. *Gujarat: Sardar Patel Renewable Energy Research Institute* pp.7–43.

139. USAID. (2015). Greenhouse Gas Emissions in Egypt. Retrivied from: file:///C:/Users/Rania/Downloads/GHG%20Emissions%20Factsheet%20Egypt_v6_11_02-15_edits%20(1)%20Steed%20June%202016_rev08-19-2016_Clean.pdf (Accessed 10 December 2019).

140. Uzlu, E. Akpınar, A. and Kömürcü, M.I. (2011) Restructuring of Turkey's electricity market and the share of hydropower energy: the case of the Eastern Black Sea basin. *Renewable Energy* 36, pp.676–688.

141. Van den B.R. Faaij, A. and Van W.A. (1996) Biomass combustion for power generation. *Biomass Bioenergy,* 11, pp.271–81.

142. Van Hulle, F.J.L. Nath, C. Jensen, P.H. Eriksson, C. and Vionis, P. (2001) European Wind Turbine Certification Guidelines. EWTC, pp.1-45. Available at: https://publicaties.ecn.nl/PdfFetch.aspx?nr=ECN-C--01-059 (Accessed 15 July 2019).

143. Wang, S., & Ge, M. (2019). Everything You Need to Know About the Fastest-Growing Source of Global Emissions: Transport. *World Resources Institute.* Retrieved from: https://www.wri.org/blog/2019/10/everything-you-need-know-about-fastest-growing-source-global-emissions-transport. (Accessed 6 November 2019).

144. Wizelius, T. (2007) Developing wind power projects: theory and practice. *Earthscan. London, UK*. pp. 1-304.

145. Zhang, X. Zhao, X. Smith, S. Xu, J. and Yu, X. (2012) Review of R&D progress and practical application of the solar photovoltaic/thermal (PV/T) technologies. *Renewable and Sustainable Energy Reviews,* 16(1), p.599–617.

146. Zhao, J. Song, Y. Lam, W-H. Liu, W Liu, Y. Zhang, Y., et al., (2011) Solar radiation transfer and performance analysis of an optimum photovoltaic/ thermal system. *Energy Convers Manage,* 52(2), pp.1343–1353.

147. Zondag, H. (2008) Flat-plate PV–Thermal collectors and systems: a review. *Renewable and Sustainable Energy Reviews,* 12(4), pp.891–959.