QATAR UNIVERSITY

COLLEGE OF ENGINEERING

DESIGN OF HYBRID RENEWABLE ENERGY SYSTEM FOR NEAR ZERO ENERGY BUILDING IN QATAR

BY

MAI HAMAD M A FETAIS

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COMMITTEE PAGE

The members of the Committee approve the Thesis of Mai Fetais defended on 16/05/2017.

Dr. Tarek El Mekkawy
Thesis/Dissertation Supervisor

Dr. Ali Razban
Committee Member

Dr. Andrei Sleptchenko
Committee Member

Dr. Mohamed Ayari
Committee Member

Approved:

Khalifa Al-Khalifa, Dean, College of Engineering

ABSTRACT

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Title: DESIGN of HYBRID RENEWABLE ENERGY SYSTEM for NEAR ZERO ENERGY BUILDING in QATAR

Supervisor of Thesis: TAREK, El Mekkawy.

Environmental development is the fourth pillar of Qatar National Vision 2030, which has been launched to draw a clear roadmap for the future of Qatar. The vision is aiming towards a balance between developmental needs and the protection of Qatar’s natural environment, including land, air and sea. As a contribution to the vision, this thesis is produced. People nowadays have awareness about renewable energy and its benefits. However, renewable energy sources are unpredictable and changeable with climate change. The best solution to overcome these challenges is to combine multiple renewable energy sources in one energy system. Combining multiple RE sources provides reliable system that meets the energy demand. It is very important in designing a hybrid system to optimally size the system components as sufficient enough to meet the load requirements with minimum total costs. In this thesis, an optimal sizing of a hybrid renewable energy system for an existing building is proposed. The aim is to maximize the renewable energy ratio of the building and to minimize the total net present worth of cost as well as CO_2 emission. The proposed hybrid renewable energy system (HRES) consists of solar panels, wind turbines and waste energy management plant. Furthermore, a connection to the National grid is provided, where the proposed system can buy and sell from and to the grid. In this study a year collected data are used to calculate hourly power of PV panels, wind turbines and waste boilers for the whole year. Different designs with different combination of renewable energy sources are generated to match the demand of an existing building. The design with low considerable cost and low considerable CO2 emission id considered the optimal solution.

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A_{PV}	Are of PV panel installed on the building roof [m^2]
A_r	Wind turbine rotor swept area [m^2]
$C_{elec,s}$	Electricity price sold to the grid [CAD/kWh]
$C_{elec,b}$	Electricity price bought from the grid [CAD/kWh]
$C_{I,j}$	Capital cost per unit for component j [CAD/unit]
C_P	Wind turbine power coefficient
$C_{O\&M,j}$	Operation& maintenance cost per unit for component j [CAD/unit]
$C_{rep,j}$	Replacement cost per unit for the component j [CAD/unit]
CRF	Capital recovery factor
E_{EX}	Excess electricity should be sold or bought[kWh]
$El_{s,y}$	Annual sold electricity to the grid [kWh/year]
E_{bought}	Bought electricity from the grid [kWh]
E_{Sold}	Sold electricity to the grid [kWh]
$\mathrm{E_{PV}}$	Net power generated by PV panel [kWh]
$\mathrm{E_{WT}}$	Net power generated by Wind turbine [kWh]
EF_E	Emission factor for grid electricity [kg CO$_2$/KWh]
$El_{b,y}$	Annual electricity bought from the grid [kWh/year]
EOT	Equation of time[min]
i	Interest rate [%]
$I_{b,n}$	Direct normal irradiance [kWh/m^2]
$I_{b,tilt}$	Beam radiation [kWh/m^2]
$I_{d,tilt}$	Sky diffuse radiation [kWh/m^2]
$I_{r,tilt}$	Ground reflected solar radiation [kWh/m^2]
I_T	Total solar radiation on tilted surface [kWh/m^2]
K	Single payment present worth
L_{local}	Local longitude[Degree]
LST	Local standard time

$\mathrm{P_{j,max}}$	Upper limit for components capacity
$\mathrm{P_{j,min}}$	Lower limit for components capacity
P_r	Wind turbine rated output power [kW]
P_{PV}	PV panel capacity [kW]
P_{WT}	Wind turbine capacity [kW]
RER	Renewable energy ratio[%]
T	Project life time[year]
t_{zone}	Time zone difference
V_C	Wind turbine cut-in wind speed [m/s]
V_f	Wind turbine cut-off wind speed [m/s]
V_r	Wind turbine rated wind speed [m/s]
Z	Wind turbine hub height [m]
η_{pv}	PV panel efficiency[%]
ξ	Sun azimuth angle [Degree]
ε	Tilt angle [Degree]
λ	Latitude[Degree]
δ	Solar declination angle [Degree]
χ	Zenith angel [Degree]
ζ	Plate azimuth angel [Degree]
ρ	Air density [kg/m^3]

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I would like to express my gratitude to all those who gave me the opportunity to finish this thesis. Special thanks go to my supervisor, Dr. Tarek El Mekkawy, for his directives and guidance through the work. My deepest appreciation to KAHRAMAA Utility "Qatar General Electricity and Water Corporation" and Ministry of Municipality and environment for providing the needed data. Last but not least sincere thanks to my family and friends; who supported me, while working in this thesis.

Chapter 1 - Introduction

1.1. Overview

Buildings account for approximately 40 percent of global energy consumption. This results in an estimated 36 percent of all carbon dioxide emissions. Owing to this high rate of emissions, it is important to use energy sources with lower emission rates. One approach is using renewable sources of energy. However, in some cases, it is difficult to find a single source of renewable energy that can meet all energy needs of a building. In such cases, a combination of two or more renewable energy sources is suggested. These energy sources supplement each other in order to supply the required energy load. This has contributed to the concept of hybrid renewable sources of energy (Erdinc & Uzunoglu, 2012).

1.2. Research Motivation

Energy is the most vital component of nations' development. Implementing systems with renewable sources shall provide solutions to political and environmental challenges. Within the past few years, different technological innovations were introduced. All of these innovations were focusing on lowering the cost, minimizing emissions and increasing efficiencies. All forecasts illustrate that the world energy demand is growing over the next years. This growth means that production of fuel will grow to sustain the electricity demand, which will lead to more carbon dioxide emission and shall have negative effect on the environment. (Meisen & Pochert, 2006)

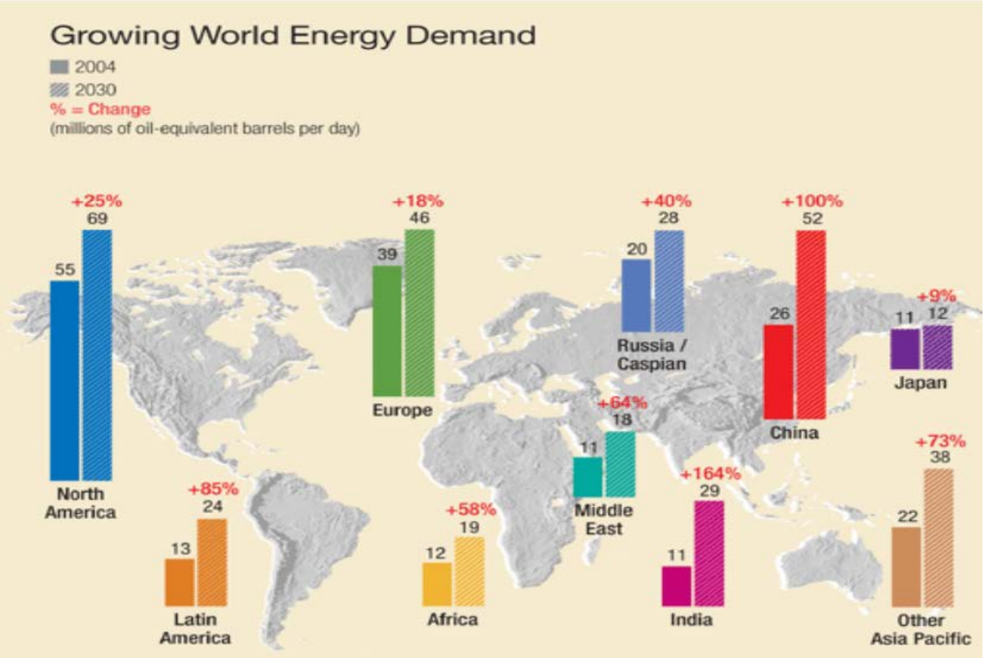

Figure 1 The world energy outlook for 2030 by region (Meisen & Pochert, 2006)

Figure 1 is showing high percentage of future demand of energy in middle-east that reaches to 64%. Having an increasing percentage of energy form conventional sources such as oil and diesel means producing more CO2 will be produced. Hence, we have to use other renewable sources of energy to meet the increasing demand of energy and in the same time reducing the carbon dioxide emission.

1.3. Environment and economic aspects

The production of electric power is the main contributor to global warming, and it affects negatively the environment. Increase of conventional production of electric power has severe and regional impacts. To avoid polluting the environment while meeting the demand, renewable energy shall be introduced. Among all the primary renewable sources, solar energy offers the highest potential. Solar offers no noise, no movement, no smoke, no dust, nor waste. In addition to that solar energy will never run out. The cost of solar power is expected to compete with conventional sources in coming years. (Meisen & Pochert, 2006)

The amount of carbon dioxode that can be produced per kilowatthour for specific fuels and specific types of generators by multiplying the CO2 emissions factor for the fuel by the heat rate of generator. Table 1 shows the number of pounds of CO2 produced from different fuels and the resulting amount of CO2 produced per KWh. (Administration, 2016)

Table 1 Energy Information Administration amount of CO2 per fuel type. Last updated: Feb 29, 2016

Fuel	Pounds of CO2 per million Btu	Heat rate (Btu per KWh)	Pound of CO2 per KWh
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
Distilate oil	161.290	10.156	1.64
Residual oil	173.702	10.156	1.76

To calculate the amount of fuel used to generate a kilowatthour of electricity, two formuals shall be used(EnergyInformationAdministration, 2016)

- Amount of fuel used per KWh = Heat rate (in Btu per KWh)/ Fuel heat content (in Btu per physical unit)
- Kilowastthour generated per unit of fuel used = Fuel heat content (in Btu per physical unit)/ Heat rate (in Btu per KWh)

1.4. Renewable energy in Gulf Region

The gulf cooperation council countries are abundant with high solar radiation and clear sky throughout the year. it lies within the solar belt. The average annual temperature is not less than 26^{o}C. Six months of the year, the GCC countries are not in comfort zone, where they need air conditioning. Table 2 illustrates the potential of renewable energies in GCC countries. (Alnaser & Alnaser, 2011)

Table 2 the performance of renewable energy indicators in the GCC countries. (Alnaser & Alnaser, 2011)

Country	Wind (h/y)	PV (KWh/m2/y)
Bahrain	1360	2160
Kuwait	1605	1900
Oman	2463	2050
Qatar	1421	2140
KSA	1789	2130
UAE	1789	2360

1.5. RE in Qatar

Qatar is opting for huge investment and utility of renewable energy. There are several projects in renewable energy in Qatar. Qatar has the capacity to provide the required power supply till 2015 and to meet the increasing demand.

Qatar Developed huge power generations to ensure that there is sufficient power to meet an expected growth in demand. Qatar government is investing $140-billion budget for infrastructure (electricity) and business expansion as per According to Gulf Construction Magazine. (Alnaser & Alnaser, 2011)

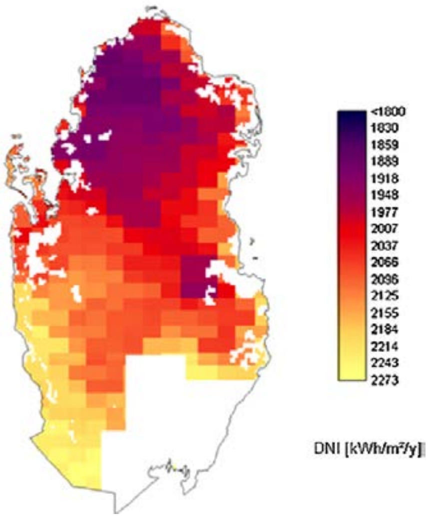

Figure 2: the concentrated solar thermal potential in Qatar

Figure 2 shows the solar potential in Qatar. Qatar's total area is 11,437 Km2. The percentage of the area needed for renewable energy to fulfill the future need is 0.2% of the land.

1.6. Objectives

The aim of this study is to increase the renewable energy ratio of a building while minimizing cost and emissions. The energy system includes wind turbine, PV panels, waste boilers, in addition to the connection of the grid. Grid is utilized as backup when the renewable energy sources are not able to meet the load.

This thesis aims to develop a design, which shall feed a building with minimal emissions and cost.

The study is done in using different percentage of the system as renewable energy source. The study discussed using 10% of the system from renewable energy sources, then using 15% of the system for RE sources and with 50% of the system from RE sources. These are significant for decision maker as their decision shall be make taking in consideration different aspects as environmental, economical and political aspects.

1.7. Thesis outline

This thesis consist of 6 chapters. This chapter provides an introduction to the thesis. Chapter 2 introduces the background and literature review. It describes the renewable energy sources, advantages and disadvantages of renewable sources. It also presents the hybrid renewable energy system with reasons to use and describes the methods of optimization.

Chapter 3 explains the problem formulation of this study and Chapter 4 introduces the proposed optimization approach. The performed experiments and obtained results are illustrated in chapter 5. Chapter 6 shows the conclusion and future work for this thesis.

Chapter 2 - Background and Literature Review

2.1. Zero Energy Building

A zero energy building (ZEB) has been defined as a building whose energy needs have been greatly reduced by improving its energy efficiency gains and that its extra energy requirements are met by renewable energy technologies. The concept of renewable hybrid energy systems and zero energy buildings are inseparable because the first objective of a ZEB design is to optimize energy efficiency then use renewable energy available on site (Li, Yang, & Lam, 2013; Torcellini, Pless, Deru, & Crawley, 2006). Interest in ZEB has being growing due to the need to reduce energy costs and also to minimize environmental consequences arising from the use of fossil fuels as energy sources. Renewable energy sources have also found wide acceptance for buildings in remote off-grid locations. Documented evidence suggest commercial and residential buildings energy use in the US account for approximately 40% of primary energy and 70% of the electricity consumed. Renewable energy technologies that can be exploited include solar energy, wind energy, biomass, geothermal, and biogas.

Defining zero energy building depends on boundary and the metric of the building. The project goal and the values of the design team and building owner effect the definition of zero energy building. Different stakeholders have different definition. For example, the owner of the building care about cost the most, while government organizations will care mostly with national numbers. The designer is concerned about using of energy code requirements, stakeholders who are caring about pollution from power plants and burning of fossil fuels are interested in reducing emissions. So the mostly used definitions of zero energy building are net zero site energy (defined by designer), net zero source energy (defined by government), net zero energy costs (defined by owner), and net zero energy emissions (defined by people caring about environment).

US department of energy defines ZEB as follow:

- Net Zero Site Energy: A site ZEB produces at least as much energy as it uses in a year, when accounted for at the site.
- Net Zero Source Energy: A source ZEB produces at least as much energy as it uses in a year, when accounted for at the source. Source energy refers to the primary energy used to generate and deliver the energy to the site. To calculate a building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.
- Net Zero Energy Costs: In a cost ZEB, the amount of money the utility pays the building owner for the energy the building exports to the grid is at least equal to the amount the owner pays the utility for the energy services and energy used over the year.
- Net Zero Energy Emissions: A net-zero emissions building produces at least as much emissions-free renewable energy as it uses from emissions-producing energy sources. (Torcellini, Pless, Deru, & Crawley, 2006)

2.2. <u>Pollution</u>

Latest data published by the US Energy Information Administration Emissions ranking and country provides a unique picture of economic growth – and decline. Qatar is ranked 51 in CO2 emissions in the world in 2008 and 7th in Middle East with 66 million tons of CO2 emissions in 2009.

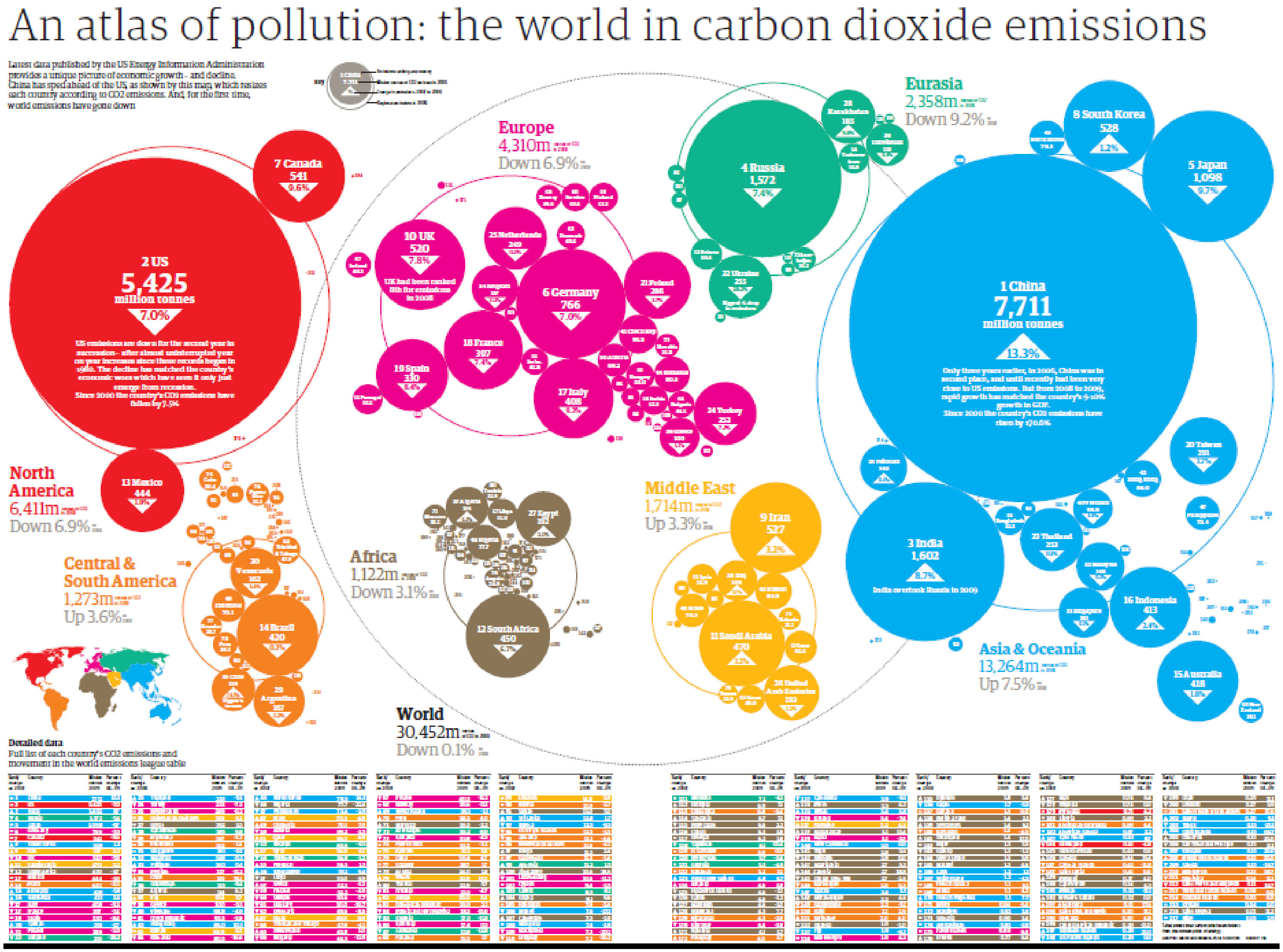

Figure 3: Atlas of pollution reference to US Energy Information Administration

2.3. RE sources

Hybrid renewable energy sources had been studied by several researchers. (Panwar, Kaushik, & Kothari, 2011) reviewed the renewable energy sources to define the role of the renewable energy sources in protecting the environment. In their study, it is emphasized that renewable technologies are clean energy sources and optimum use of these resources minimize negative environmental impacts, produce minimum secondary wastes and provide a sustainable world.

2.3.1. Photovoltaic

The method of solar photovoltaic cells (electricity) involves generating electricity from sunlight through the use of PV cells or Photovoltaic cells, usually called Solar cells (Hamilton, 2014). Its benefit comes from the scientists who continuously design an increasing number of its dominant and effective versions. Yet, it has also some disadvantages including its high cost of making designs and the usage of polluting chemicals within the manufacturing process. The electricity is also not possible to be generated in case of not having sunny weather.

2.3.1.1. Types

2.3.1.2. Large-Scale PV systems

Thousands or hundreds of thousands individual PV cells connected in a complex web of panels, modules and arrays would form a large-scale PV system, or sometimes called a solar farm. It is designed to provide power to many users. In solar farms, PV panels, modules or arrays are connected to an inverter to invert form DC voltage to AC voltage, and then to a transformer to maximize the voltage to connect into the utility grid. (Gibilisco, 2013)

Some of the advantages of large-scale PV system:

1. Supply is unlimited as sunlight is a renewable source.

2. No greenhouse gases are generated.

3. PV cells make no noise.

4. No need of large towers or buildings that will mar the landscape.

Some of the limitation of large-scale PV system:

1. Solar power is discontinuous and cannot be stored on large scale.

2. Solar power cannot totally satisfy the electrical needs of a city or nation.

3. The panels must be mounted on movable bearings in order to get an optimum performance.

4. Require a dedicated real estate.

5. Hail and wind storms may destroy solar panels, modules and arrays.

2.3.1.3. *Small-Scale PV systems*

Small scale PV systems refer to systems that shall produce enough energy under ideal conditions. In order for such systems to provide a continuous supply of energy it is essential to use storage devices or an interconnection to the electric grid or both.

Small scale PV systems can be stand-alone systems, Interactive system with battery or Interactive system without batteries. (Gibilisco, 2013)

Some advantages of small-scale PV system

1. As in large scale, supply in such systems is unlimited.

2. PV cells make no noise

3. generate no greenhouse gases or other pollution.

4. can supplement other electric energy sources.

5. has low profile.

6. for system with no batteries, maintenance is not required.8.

Some limitations of small-scale PV system

1. Provide energy when there’s enough sunlight.

2. load imbalance is major in small scale systems.

3. for off grid systems, a person have to make sure the current demand from the system does not exceeds its maximum deliverable current.

2.3.2. Wind Power

The blades of a turbine are often blown through the gusts of wind, resulting in the turning of an energy generator. From this occurrence, the wind method is applied to create electricity from the same energy generator. The benefit of wind method is the production of a huge volume of electricity specifically in the windy environment or having windy turbines. The disadvantage is its noisy turbines that force the habitats to dislike them and term them simply ‘an ugly alternative source of renewal energy’. (Nersesia, 2010)

2.3.3. Fossil Fuels – Biofuels power

The biofuels have two kinds that have a possibility of adding to the fossil fuels, making its lasting for a long period. The first kind of biofuel is biodiesel that is produced through the palm, sunflower, and oily crops. The second kind of biofuel is bioethanol that is generated through all plants, but its presently utilized sources of production are wheat and sugar. The benefit of biofuels method is as such that they support in taking out carbon dioxide from the environment, thereby offering a healthier atmospheric condition. The disadvantage of biofuels is the prevention of harvesting food crops because the farmers need the intensive cultivation of crops that often cause damages to the habitats. Another serious disadvantage is the health-affecting atmosphere that occurs due to the spreading of carbon in case of burning the biofuels.

2.3.4. Hydro-electric power

Under the hydroelectric power (HEP) method, a lake is formed behind the dam by developing a dam over the rapid flowing river. Afterward, the lake water is made flowed from the sides of turbines within dam walls, generating the electricity up to the maximum level possible. The benefit of the hydroelectric power method is to store electricity in the best way possible. The disadvantage is the high cost of building hydroelectric dams. These could also cause serious damages to the nearby dwellers if these dams start flooding new regions of lands and drying up the other parts.

2.3.5. Tidal Energy power

The tidal energy method is applied when the huge volume of seawater moves with the rotation of the earth on one hand and then the water is attracted on the earth's surface by the moon on the other. A large volume of energy generates from this two-way tidal system and subsequent movement of water. Afterward, the energy-based water is stored and made flowed through turbines, making the possibility of generating substantial electricity. The tidal energy method is one of the reliable sources of electricity because the levels of the sea are not changed within the areas (Ebinger & Vergara, 2011). The disadvantage is its high cost of developing the tidal barrages. These could also cause damages to the nearby dwellers from both sides of the barrage. There is even a possibility of getting birds, fish, and similar wildlife sucked in the turbine.

2.3.6. Wave power

The waves usually move water where every wave turns a quiet little turbine. Under the wave method, the spectrum of tiny turbine mechanisms are made floated over the sea upper side particularly for collecting the energy, making the possibility of generating a huge volume of electricity (Spies, Pollak, & Mateu, 2015). The benefit of wave method includes the capturing of energy on one hand, and the reduction of rough seas on the other in case of not collecting such generated energy. The disadvantage is the occupying of a vast level of the area that also creates difficulty for shipping in moving around.

2.3.7. Geo-thermal power

Under this method, the turbines are turned by pumping water in the underground area whereby the water is possibly turned into steam using the heats of underground rocks. The geothermal energy method is considered as one of the reliable means of alternate energy. However, its disadvantage includes finding or getting the places having adequate hot temperature or heated underground rocks, making the generation of electricity quite difficult and even taking a lengthy period of time in searching.

2.3.8. Solar power (hot water) power

Under the solar panels (hot water) method, the huge volume of sun-produced heat radiation is used in generating electricity. As a general process, few volume of the heat is collected through the water specifically while passing via the black tubes that are open to the sunlight. The benefit of the solar panels (hot water) method is the gaining of free warm water on a daily basis following the buying and setting up of the required units. The disadvantage includes the unit produces neither very hot water nor does the hot water is available late night. There is also no availability of hot water in the cloudy season.

2.3.9. Biomass power

The biomass is every organic material, including non-edible parts of plants, waste food, animal dung, and wood. These are usually burnt as a fuel that makes the possibility of generating energy and subsequent formation of electricity. The usefulness of biomass method is similar to the biofuels method because the fuels of biomass support in taking out carbon dioxide from the environment. It has a serious disadvantage, similar to the biofuels method, such as creating a health-affecting atmosphere by bringing back the carbon dioxide in the atmosphere in case of burning. Moreover, the spreading of this carbon dioxide in the atmosphere could become the consequence of facing serious health risks for the lifetime.

2.4. Waste to energy Process

All the actions and activities involved in managing the waste from its generation to its final disposal is called the waste management. It is the precise name given to the monitoring, collection, transportation and disposal of waste. Human activities are responsible for the production of so much waste every year, so, the management of waste is necessary to avoid its adverse effect on the environment and human health. Waste can also be managed to get resources from it. All kinds of waste like solid, liquid, gaseous and radioactive matter needs to be managed.

Developed and Developing countries may have different methods of waste management. Different methods are also adopted for residential and industrial areas, for rural and urban populations. Local government has the responsibility of managing the waste in rural and metropolitan areas. Non-hazardous waste produced by industries is to be managed by the industries itself.

There are various methods of waste disposal adopted around the world like Landfill in which the waste is buried in the land. Combustion/Incineration: in this method, the municipal solid waste is burnt at such a high temperature that it is converted into gaseous and residue products. The recycling process is adopted to convert waste products into new products. Natural resources can be preserved for future use, and reducing greenhouse gas emissions. Plasma Gasification is another method of waste management which is used for the destruction of waste and dangerous material. The molecular bonds of the waste materials are broken down due to intense heat in the vessels. Composting is a natural and easy process in which the plants, kitchen and garden waste is turned into nutrient-rich food for plants. . The most efficient method of waste management can be a reduction in the creation of waste materials so that adverse effect on the human health and environment can be prevented.

Recover energy or Waste-to-energy process is used to generate energy in the form of electricity or heat from the waste products. Energy from recycling can be produced from boilers at industrial level. Gasification and Pyrolysis are two treatment methods in which materials are heated at high temperature with limited oxygen supply and the products of treatment can then be used for the energy production. (DeltawayEnergy; wrfound)

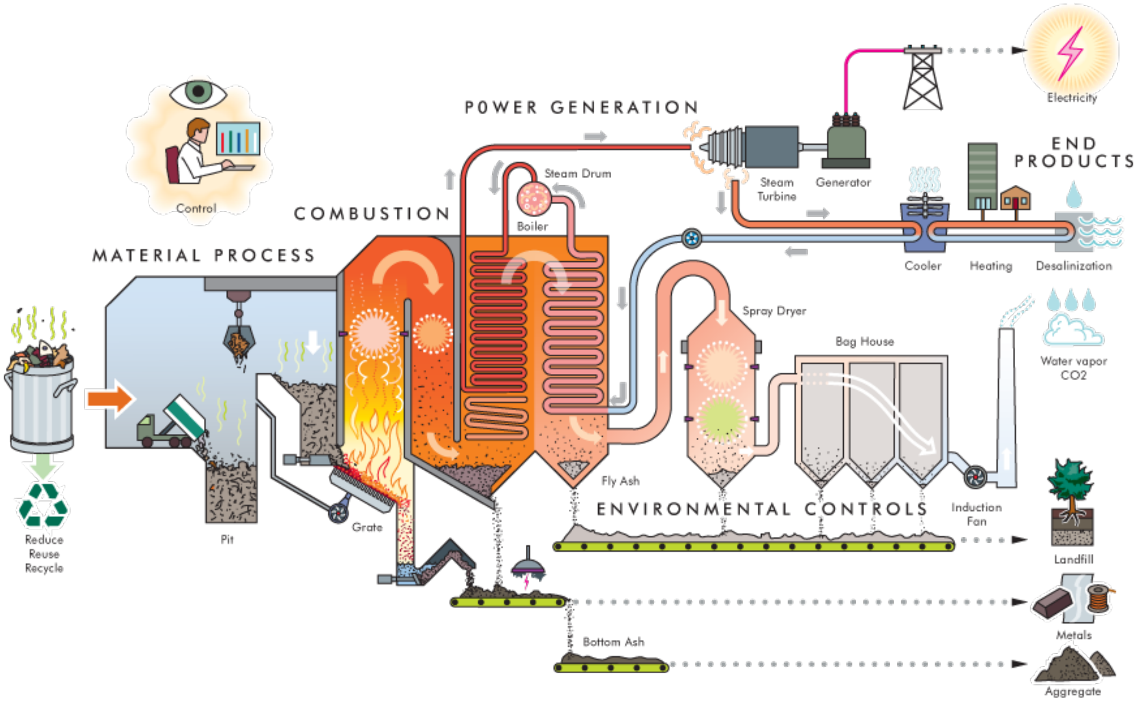

Figure 4: Process of waste to energy (DeltawayEnergy)

In order to have proper waste management around the world in all the countries, the focus should be given to improving the sound waste management facilities and operations. The waste should be reduced at source, the circular economy should be adopted instead of linear waste management. In order to have effective waste management, it should be measured properly.

GCC countries are among the countries having highest per capita waste generation rates worldwide because of fast industrial growth, rapid urbanization, increasing population, heavy construction, and lifestyles improvement. Thus, a well-developed and a uniform waste management system and a monitoring mechanism were implemented by GCC countries in December 1997 for collection, sorting, treatment and disposal of waste. The solid waste generation rates in Bahrain hav raised from around 1.3-1.6 kg to almost 2.7 kg per capita/day due to growing business, urbanization, growing family income, and increased purchasing power. Land filling, waste recycling and waste sorting methods are adopted for waste management at present (Abou-Elseoud, 2008).

Sustainable solid waste management plans have been adopted by the GCC countries to maximize embodied environmental value. A vital component of the future efforts is to provide Integrated Solid waste Management schemes which are aimed at managing solid waste with all available means i.e. recycling, composting, combustion, land filling and disposal, eco design, Avoidance/reduction and resource recovery (Al.Ansari, 2012).

Waste-to-energy is an emerging market in the GCC countries, which is growing at a very high pace due to high waste generation per capita. Municipal solid waste is effectively converted into fuels and energy by adopting various advanced thermal technologies, like gasification and pyrolysis. WTE projects in the GCC countries have an estimate of producing 300 MW- 500 MW of power by 2020 which is around 10 times the current WTE production (Zafar, 2015).

One of the fastest growing economies of the world is of Qatar and one of the most serious challenges faced by this nation is that of municipal solid waste management due to urbanization, high population growth, economic expansion and industrial growth. The per capita waste generation rate of the country is as high as 1.8 kg per day. Every year, more than 2.5 million tons of the solid waste is produced in the country (Zafar, 2015). The waste of energy generation facility has also been established in Qatar to treat waste and supply electricity to the grid.

According to a report by Qatar development bank, it has been reported that an estimated revenue of around 663 million dollars can be obtained by recycling and by producing energy i.e. from waste-to-energy. 28000 tons of garbage were produced by Qatar per day in 2012 which was 7 percent more than that in 2011. Most of this waste are from hazardous materials, construction materials and domestic refuse, etc. Qatar is the first GCC country to implement WTE on a large scale. An integrated Domestic Solid Waste Management Centre (DSWMC) has been established at Mesaieed to maximize waste-to-energy and resources recovery, which is one of the largest compost plants in the world and cost around 2 billion dollars. Thus, Qatar is adopting many waste management strategies to manage the ever-increasing waste generated in the country.

2.5. **Applicability / Technical Limitations / challenges**

(Angelis-Dimakis et al., 2011) assessed the availability of renewable energy sources. A detailed study including existing tools and methods to determine the possible energy in renewable sources is obtainable in their work. Most developed countries tend to use renewable energy to reduce the emissions of carbon dioxide. Their work also discuss the usability of hybrid energy system by mixing different renewable sources.

Introducing the near zero energy building concept with the huge tendency towards including renewable energy sources in facilities require completely new energy supply system designs to fulfill the balancing condition and to cover the building demand in an efficient way. The precise consumption of the building, possibility of grid connections, energy storage systems as well as the on-site energy availability in form of detailed weather data have to be taken into account when designing and operating these supply system. In addition to that, these systems tends to cause considerable high investment costs comparing to conventional systems. Thus, a cost optimized design is necessary. With these challenges and requirements, there shall exist some tools to assure and enhance the widespread implementation of near zero energy buildings. A methodology that allow for identifying cost optimized supply system design is crucial. It should assure that a large variety of different supply options is evaluated during the optimization process. In addition to that, it should be capable of adding new technologies without obstacles.

2.6. Design of a building (Insulation, windows)

Research shows that buildings account for a large percentage of global energy consumption and consequently carbon emissions. The idea of formulating sustainable strategies in the context of energy consumption often involve measures to increase energy efficiency in buildings and increase the utilization of clean energy systems. The ultimate design strategy of a building that is ZEB compliant results in high efficiency leading to minimum energy consumption and subsequently minimum carbon emissions and the use of renewable energy technologies to complement the extra balance of energy required. Researchers interested in finding solutions usually breaks down the energy loads of a building into specific units for ease of study and simulation. For example, majority of energy consumed in buildings has been found to be heating and cooling. Other areas that involve use of energy involve equipment such as escalators, lighting, and other machines. Design of effective energy efficiency measures requires a study of the three major aspects of a building: building services systems, building envelope, and internal conditions. Building envelopes include a consideration of building’s features such as window glazing, day lighting, thermal mass, thermal insulation, reflective or green roofing. Indoor conditions include study of indoor design conditions as well as internal heat loads, which can be due to lighting, equipment or appliances. Building services systems include heating, ventilation, and air conditioning systems (HVAC systems); electrical services including lighting; and heavy machines such as escalators and lift services (Li, Yang, & Lam, 2013).

The building services systems, building envelope, and internal conditions of a building are studied in detail with an objective of incorporating element of energy efficiency. For example, the analysis might recommend a replacement of energy consuming incandescent light bulbs be replaced with more energy efficient LED light bulbs or if the building loses a lot of energy in winter, the idea might be to insulate it to improve its thermal performance. Even after all this has been done, it is very likely that the building still requires some energy to power equipment like lifts, escalators, energy efficient bulbs etc. however, due to energy efficiency, the final energy required might be very small compared with the initial energy requirements prior to assessment. That extra energy required can be obtained from various sources. However, since the overall objective is to save money and conserve environment, the next best alternative is to choose renewable systems. Where more than one source of renewable energy system is available onsite, the idea is usually to exploit all of them by tapping and using them in a hybrid system. However, in some situations, one type of system such as solar power might be available relying on photovoltaic as the sole energy might preset some challenges. A study conducted by (Scognamiglio & Røstvik, 2013) content that photovoltaic power is not good for ZEBs as the sole energy source due to their intermittent nature.

2.7. Hybrid Renewable Energy

Technological advancements in aspects of design, optimization, operation and control has made it possible to integrate two or more renewable energy systems (such as wind and solar) to obtain a renewable hybrid energy system configuration (Bajpai & Dash, 2012). The results have been development of new, innovative, clean, and efficient energy systems that compliment other efforts made in the designs of ZEBs.

(Prasad & Reddy, 2011) studied the possibility of incorporating renewable hybrid energy sources in ZEBs. Their objective was to understand the environmental and economic benefits of integrating renewable energy system in ZEBs. Their study involved collection and analysis of data about energy requirements. From the results, they suggested ways of ensuring how ZEBs can be achieved with incorporation of renewable hybrid energy systems. In their study, they considered a photovoltaic-wind hybrid system for ZEBs. The hybrid system architecture was composed of a PV array, a wind turbine, a generator, storage battery, inverter, rectifier, and dispatch strategy cycle charging. An existing building was chosen and simulations were performed based on the collected and analyzed data of energy the building's energy requirements. The results of the simulations of the old building was then compared with the simulations of a modified building with the demonstration of how such a solar-wind hybrid system could effectively feed the modified building's load. A HOMER software was used in the simulations. The results of the simulations suggest renewable hybrid systems are feasible for integration in Zero Energy Buildings. Their findings also suggested that besides offering solution for ZEBs, the hybrid system also has economic and environmental benefits.

In an attempt to find a solution for a typical zero energy building, Lu and Wang (2014) came up with an optimal design for renewable hybrid energy systems. They chose Hong Kong Zero Carbon building with its meteorological data of 1987 as their reference point for their study. They were able to generate the annual cooling load profile of the building with the use of a TRNSYS building model. Among the building's data collected used as a basis for load profile included aspects of lighting schedule, occupancy schedule, equipment energy consumption, electricity energy demand, air conditioning, and energy generation values. In order to simulate the energy systems of the building, they had to first develop simplified models of renewable energy systems and air-conditioning systems using a Matlab software. The building's annual load profile was taken as the input. Among the variables they optimized were wind turbine, solar photovoltaic, and bio-diesel generator that were going to form the renewable hybrid system for the building. The values of solar, wind and bio-diesel were just trial values varied accordingly to simulate the anticipated circumstances and a possibility of generating the best combination possible that factors in elements of economics, environment, and the overall concept of ZEB. Finally, the results of the performance of the building with varied combination of the renewable energy system sizes was used to perform comparative analysis and system evaluations. (Lu & Wang, 2014)

2.8. Reasons to use hybrid RE

The main driving force behind the use of hybrid renewable sources of energy is to attain near zero buildings. In near Zero energy buildings, production of greenhouse gases and overall use of energy is reduced. This is the main reason why energy use is considered to be approaching zero in such buildings. Combination of different renewable energy sources results in improved system efficiency besides providing a greater balance in the supply of energy (Fabrizio, Seguro, & Filippi, 2014).

There is one main instance when hybrid renewable energy sources are preferable in buildings. This is when there is no single renewable energy source that can meet energy needs of a building. For instance, considering the total energy requirement for a building to be 100 percent, 60 percent of this energy can be obtained from a biomass system while the remaining 40 percent can be obtained from wind energy. Therefore, such a combination would provide all the energy needed in such a building (Erdinc & Uzunoglu, 2012).

Additionally, variations in seasons make hybrid renewable energy systems suitable in buildings. This is because different systems would perform differently during different seasons. A good example is the combination of wind turbines and photovoltaic array. During winter, wind turbine is likely to provide a higher energy output when compared to solar panels. On the other hand, these solar panels would provide a higher energy output during summer. This means that there will be no period of time when there will be the need to use fossil fuels or other forms of non-renewable sources of energy in buildings (Erdinc & Uzunoglu, 2012).

2.9. Examples of systems that make hybrid RE

In order to achieve a near Zero energy building, a number of aspects need to be considered. These aspects are particularly considered during the building design process. A good example is the combination of an efficient ventilation system with solar heating systems. A properly designed ventilation system ensures that natural lighting is used during the day. Additionally, such a system would eliminate the need for cooling and heating systems which would translate into higher energy consumption. On the other hand, the presence of solar heating system reduces the need for using systems such as generators in heating. Generators use oil for energy generation which is a non-renewable source of energy. In brief, the reason for the use of hybrid renewable sources of energy is to complement each other in the supply of required load. This translates to greater efficiency in the provision of the required load (Singh, Bhupendra, Kumar, & Pandey, 2012).

2.10. Summary

All reviewed studies show that renewable energy sources are a potential to provide desired demand while avoiding environmental and political negative impact of conventional methods. Solar Energy is the highest potential to be used in middle east and countries within the solar belt. The second highest potential is wind turbines. Most reviewed studies worked with single objective function which is to minimize cost. Different software were used to simulate the proposed system as HOMER, MATLAB, and others. Below table shows a summary of the reviewed studied .

Table 3 summary of reviewed studies

#	Tilte	Authors	Citation	Region	Method	Wind turbine	PV panel	Solar collector	Biomass	water turbine	Heat Pump	fuel cell	PEV storage	Diesel	Objective functions	Heating	Cooling	Electricity	Hot water	Transportation	Approach
1	Optimum design of hybrid renewable energy systems: Overview of different approaches	O. Erdinc, M. Uzunoglu	72	NA	NA	NA	NA	NA	NA		NA		NA	NA	NA	NA	NA	NA	NA	NA	NA
2	Simulation and optimization of a stand-alone power plant based on renewable energy sources	G.N. Prodromidis, F.A. Coutelieris	0	UK	MOP	x	x			x		x		x	minimize NPC minimize CO2 emission			x			Simulation
3	Design and optimization of hybrid renewable energy system (2mwh/d) for sustainable and economical power supply at jec Jabalpur	Madhav Singh Thakur, Bhupendra Gupta, Veerendra Kumar, Mukesh Pandey	0	India		x	x					x		x	minimize NPC			x			Simulation
4	Multi-objective optimal design of hybrid renewable energy systems using PSO-simulation based approach	M Sharafi, TY ELMekkawy	12		MOP	x	x	x				x	x	x	minimize TC, while CO2 emission is constraint						PSO simulation
5	Renewable energy system optimization of low/zero energy buildings using single-objective and multi-objective optimization methods	Yuehong Lu, Shengwei Wang* ,Yang Zhao , chengchu yan	0		MOP										minimize TC minimize CO2 emission minimize grid interaction index						
6	A roadmap towards intelligent net zero- and positive-energy buildings	D. Kolokotsaa, D. Rovasb, E. Kosmatopoulosc, K. Kalaitzakisd	46																		
7	Potential for renewable energy jobs in the Middle East	Bob van der Zwaan a,b,c,n , Lachlan Cameron a , Tom Kober a	5																		
8	Influence of Dirt Accumulation on Performance of PV Panels	Shaharin Anwar Sulaiman[a], Atul Kumar Singhb, Mior Maarof Mior Mokhtara, Mohammed A. Bou-Rabeec	0																		
9	A cost optimization model for 100% renewable residential energy supply systems	Christian Milan, Carsten Bojesen, Mads Pagh Nielsen	46			x	x	x			x		x		Minimize total NPC	x	x	x	x		LP

Chapter 3 - Problem Formulation and Methodology

This study aims to describe the proposed simulation-based optimization approach, Figure 5. In this study optimization is worked by mathematical model and simulation. A heuristic algorithm approach is proposed to generate different solutions and obtain the best solution. The system have some decision variables that will define the capacity of each source. The optimal solution shall meet the study goal which is to achieve minimal cost and minimal CO2 emissions.

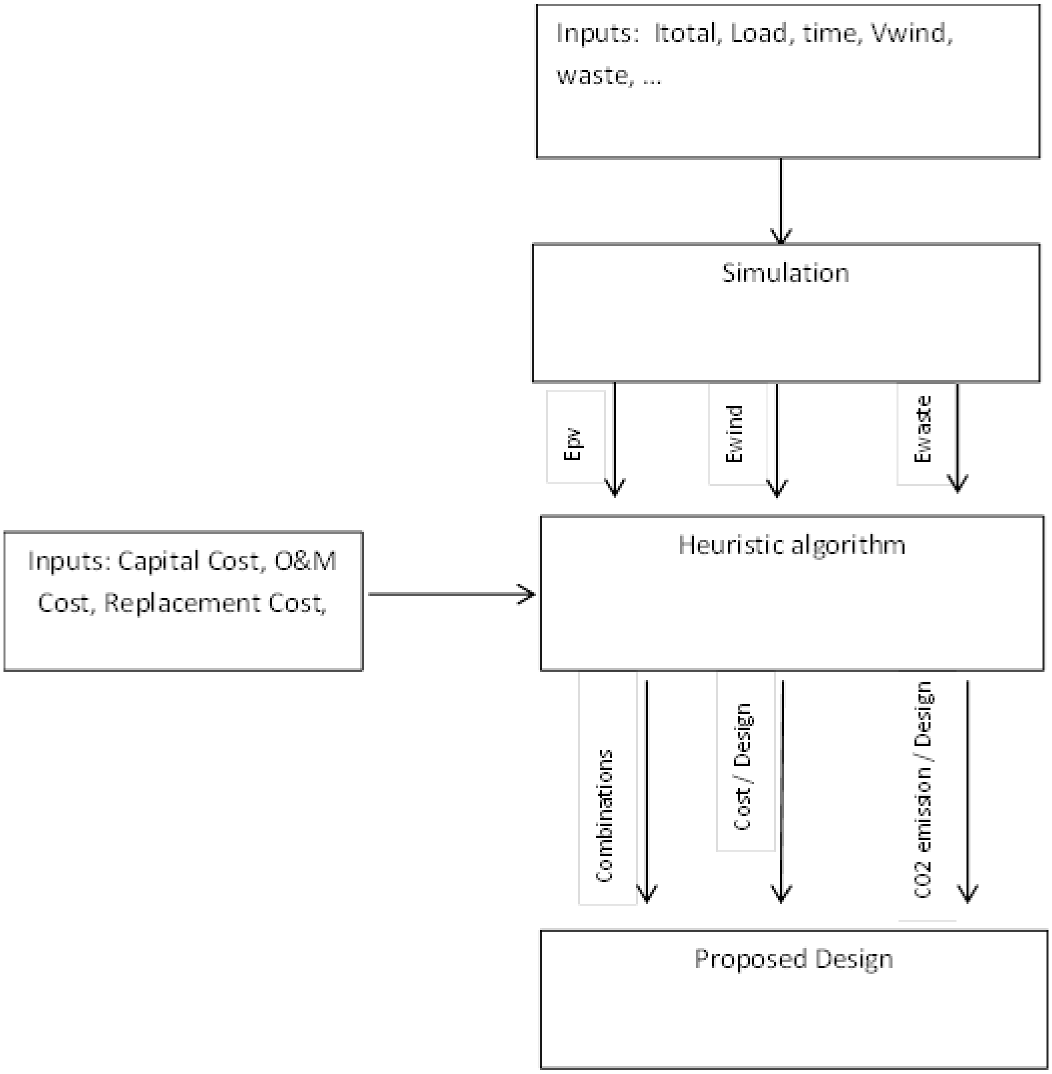

Figure 5: Problem Formulation Flow diagram

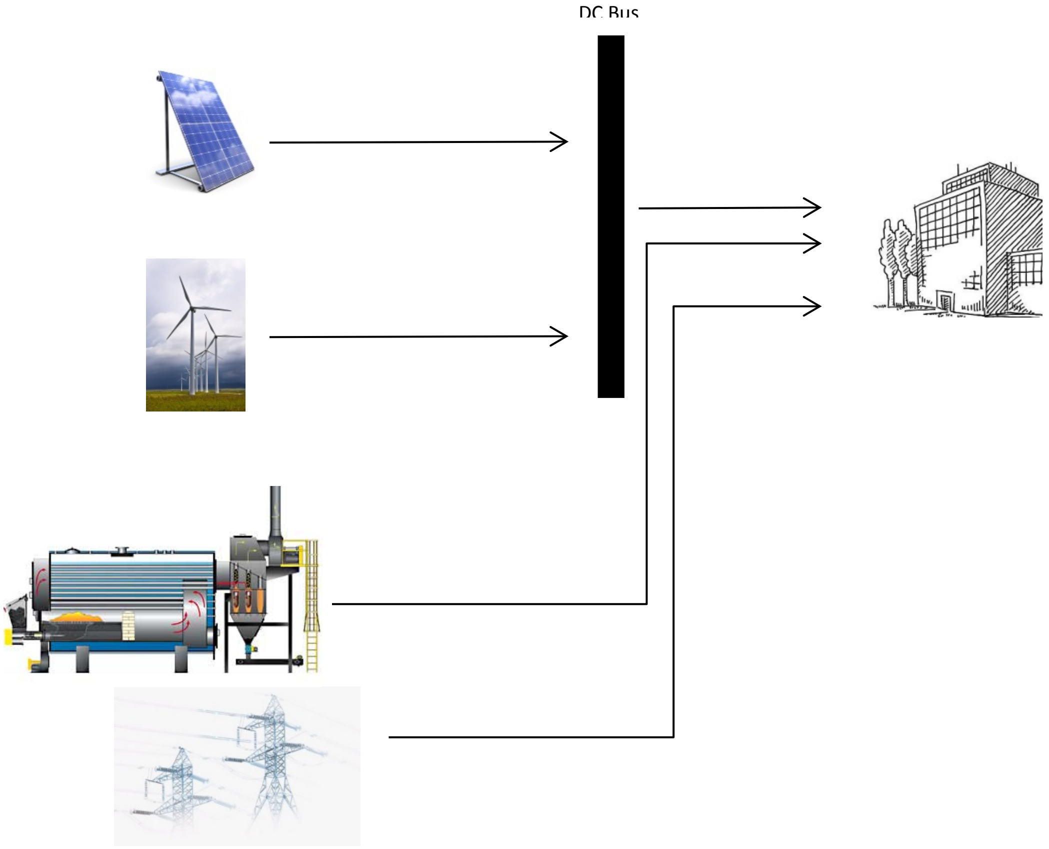

Figure 6: proposed hybrid renewable energy system

As shown in Figure 6 the proposed design consists of PV panels, wind turbines and waste boilers. In case the proposed design is not able to meet the load of the building, the grid is utilized as backup. Where if the system produced energy higher than the demand, the system shall sell energy to the grid.

3.1. Methodology

Energy demand, wind speed, temperature and solar radiation are used as inputs to the proposed simulation model. These are studied based on hourly time interval. The proposed method will calculate the hourly generated energy. Supply and demand will illustrate the renewable energy rate and yearly bought and sold energy to the grid. Renewable energy components mathematical models will be discussed in trailing.

The simulation model made of 3 components, this system calculates the generated energy for every hour.

In order to produce possible solution, these steps were followed:

1. A simulation model shall calculate the hourly energy output of each component.
2. Different scenarios of different combination of renewable energy sources shall be used to meet load.
3. Net Present Cost and CO2 emission shall be determined for each design.
4. The optimal then to be chosen.

3.1.1. PV panel Model

Solar radiation on a tilted surface having a tilt angle of ε from the horizontal and an azimuth angle of ξ is the sum of components consisting of beam ($I_{b,tilt}$), sky diffuse ($I_{d,tilt}$) and ground reflected solar radiation ($I_{r,tilt}$) (Masters, 2004):

$$I_T = I_{b,tilt} + I_{d,tilt} + I_{r,tilt} \quad \text{03-1)}$$

$$I_T = I_{tilt} = I_{b,n}[\cos(\theta) + C\cos^2\left(\frac{\varepsilon}{2}\right) + \rho(cos\chi + C)\sin^2\left(\frac{\varepsilon}{2}\right)] \quad \text{03-2)}$$

Where:

- $I_{b,n}$ is direct normal irradiance on a surface perpendicular to the sun’s rays.
- θ is the angle between the tilted surface and the solar rays.

- C is diffuse portion constant.
- ρ is the reflection index
- χ is the zenith angel.

The diffuse portion constant is used for the calculation of diffuse radiation and it depends on the month of the year. The angle between the tilted surface and the solar rays can be calculated by the following:

$$\cos(\theta) = [\cos\varepsilon\,\cos\chi + \sin\varepsilon\sin\chi\,\cos(\xi - \zeta)] \qquad \text{03-3)}$$

Where :

- ξ stand for sun azimuth angel
- ζ stand for plate azimuth angel

The electricity generated by the PV module $E_{pv,Re}$ shall be calculated on the basis of the hourly tilt radiation I_{tilt} as follow:

$$E_{pv,Re} = A_{PV} \times \eta_{pv} \times I_{tilt,hr} \qquad \text{03-4}$$

Where:

- $\boldsymbol{\eta_{pv}}$ represent the efficiency of the PV module
- $\boldsymbol{A_{PV}}$ represents the PV module area

3.1.2. Wind Turbine Model

Wind kinetic energy is converted into electrical energy in the process of wind power. Simulating wind system can be done with different ways. However the simplest model is defined by four main parameters. These parameters are cut-in speed, rated wind speed, cut-off speed and rated output power. The power generated by wind turbine in every hour can be represented by the following (Mesquita):

$$E_{WT-Re} = \begin{cases} 0 & v < V_c \\ \frac{1}{2} C_p \, \rho A_r v^3 & V_c < v < V_r \\ P_r & V_r < v < V_f \\ 0 & v > V_f \end{cases} \quad \text{03-5)}$$

Where:

- C_p represents the wind turbine power coefficient.
- ρ represent air density (kg/m^2).
- A_r is rotor swept area (m^2).
- v is wind speed (m/s).

The height of the wind turbine hub is an essential aspect to keep in mind. The wind speed, v, at a height of Z_{rot} meters from velocity measured at Z height ,v_{mea}, can be calculated as per equation)03-6) (MathewS.).

$$V(Z_{Rot}) = V(Z_{mea}) \frac{\ln(Z_{Rot} / Z_0)}{\ln(Z_{mea} / Z_0)} \quad \text{03-6)}$$

3.1.3. Waste to energy model

The energy generated as electricity from combustion of waste in KWh per ton can be represented as follow (Tchobanoglous, Theisen, & Vigil, 1993):

$$\mathrm{WTE}_{\mathrm{kWh}_{\mathrm{per}_{\mathrm{ton(i)}}}} = \frac{\text{Heating Value (i) . (2000lb/ton)}}{\text{Heat\_rate}} \quad \text{03-7)}$$

Where:

- Heating_value(i) is the heating value of waste component i (Btu/wet lb waste component).
- Heat_rate is a measure of the efficiency of the plant, the number of Btu's fuel needed to generate one kWh. (Btu/kWh).

3.2. Mathematical formulation

In this study, the simulation model is prepared to calculate the amount of energy that can be supplied from each component. The cost of the design and CO2 that will be emitted from the system is also calculated.

Objective functions of the system

1. minimize Cost
2. maximize renewable energy ratio
3. minimize CO2 emissions

Decision variables of the model are capacities summarized as :

$\vec{P} = [P_{PV}, P_{WT}, P_{waste}]$

Where:

- P_{PV} is the PV panels capacity.
- P_{WT} is the wind turbines capacity.
- P_{waste} is the waste boiler capacity.

Cost:

- Investment cost.
- Operation and maintenance cost.
- Replacement cost.

$$Cost = \sum_{J}\left[C_{ij} + C_{OM} * \frac{1}{CRF\,(i,T)} + C_{RPJ} * K_j\right] * P_j + [C_{elec,b} \times E_{bought} - C_{elec,s} \times E_{Sold}] \times \frac{1}{CRF(i,T)} \tag{03-8)}$$

j: Component indicator.

C_{ij}: Capital cost of each unit

COM: Operation and maintenance cost of each unit

Kj: single payment present worth.

CRF: capital recovery factory

$C_{elec,b}$: cost of energy bought from the grid.

E_{bought} : Energy required to be bought from the grid to follow the demand.

$C_{elec,s}$: cost of energy to be sold to grid.

E_{sold} : Energy that can be sold to the grid.

Renewable energy ratio: the amount of used renewable energy divided by the total used primary energy.

$$RER = \frac{Renewable\ energy}{Primary\ energy} \tag{03-9)}$$

CO2 emission:

The produced CO_2 that is resulted from the emission resulted by the electricity bought from the grid can be calculated as follow:

$$CO_2 = E_{bought} \times EF_E \tag{03-10)}$$

3.3. Constraints

This study is bounded by number of constraints. These constraints could be physical, technological, legal or economical restrictions. This work focuses on technical constraints which are defined by technical characteristics of the components and by demand coverage by supply.

The below equations identify the amount of excess energy that must be sold to the grid or electricity deficit that would be bought from the grid. E_{EX} clarifies that the electricity is deficit or excess.

$$E_{EX}(t) = E_{PV}(t) + E_{wind}(t) + E_{waste}(t) \quad \text{03-11)}$$

$$If \quad E_{EX} \geq 0 \rightarrow E_{Sold}(t) = 0 \quad \text{03-12)}$$

$$If\, E_{EX} < 0 \rightarrow E_{bought}(t) = 0 \quad \text{03-13)}$$

$$CO_2 \leq \ allowable\ emission\ level \quad \text{03-14}$$

$$E_j(t) \leq \ P_J \qquad \Delta t \quad \text{03-15}$$

$$O \leq \ P_j \ \leq \ P_{j,max} \quad \text{03-16}$$

$$E_j\,(t) \geq 0 \quad \text{03-17}$$

For all components, the energy produced within each time E_j should be less than its capacity P_j 03-16. 03-17 illustrate that decision variables and energy flows should be always positive, negative values are not accepted in the system

3.4. Heuristics algorithm

A heuristic algorithm starts from an empty solution and build a complete solution by assigning values to decision variables one at a time. The algorithm works by assigning a value to a decision variable which contributes most to the objective function.

The heuristic algorithm have an advantage of being simple, it is easy to implement and usually the rules to assign the next decision variable are easy to design and intuitive. It has the benefit that it is faster and less complex than improvement algorithm and ends deterministically.

However heuristic have some drawbacks as having local or myopic view, it does not guarantee global solutions. The algorithm must be ran to the end in order to get a complete solution. (Skorin-Kapov)

Heuristic algorithm consist of five components, which are as follow (Cormen, Leiserson, Rivest, & stein, 2009) :

1. Solution is created from set of Candidates.
2. Contribution of a candidate to the solution is decided by feasibility function.
3. Assign a value to a solution by an objective function.
4. Choose the best candidate to be added to the solution by a selection function.
5. Indicating a complete solution by a solution function.

Chapter 4 - Case study

4.1. Introduction

The methodology described in chapter 3 was applied in a case study. Solar radiation, wind speed and all data required for PV panels and wind turbines models were collected from Kahramaa; Qatar General Electricity and Water Corporation. Waste incineration was collected from Qatar Municipality and Urban Planning. All data were collected hourly for one year. The study was implemented in one existing building at Qatar University with consumption of 2075800 KW/year.

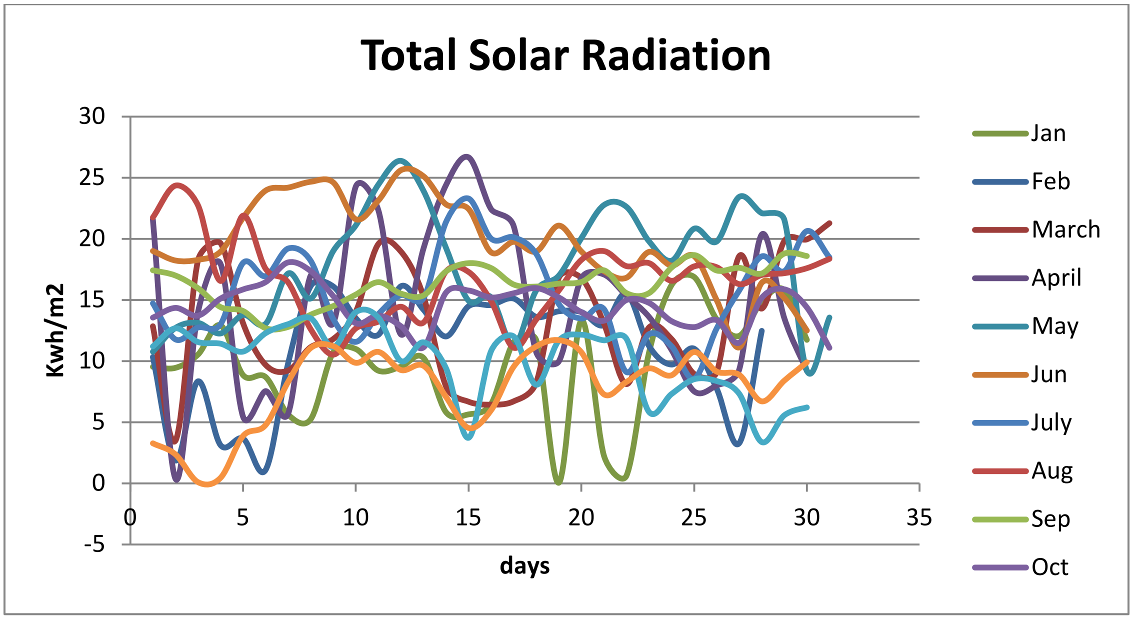

Figure 7 Collected Daily total solar radiation

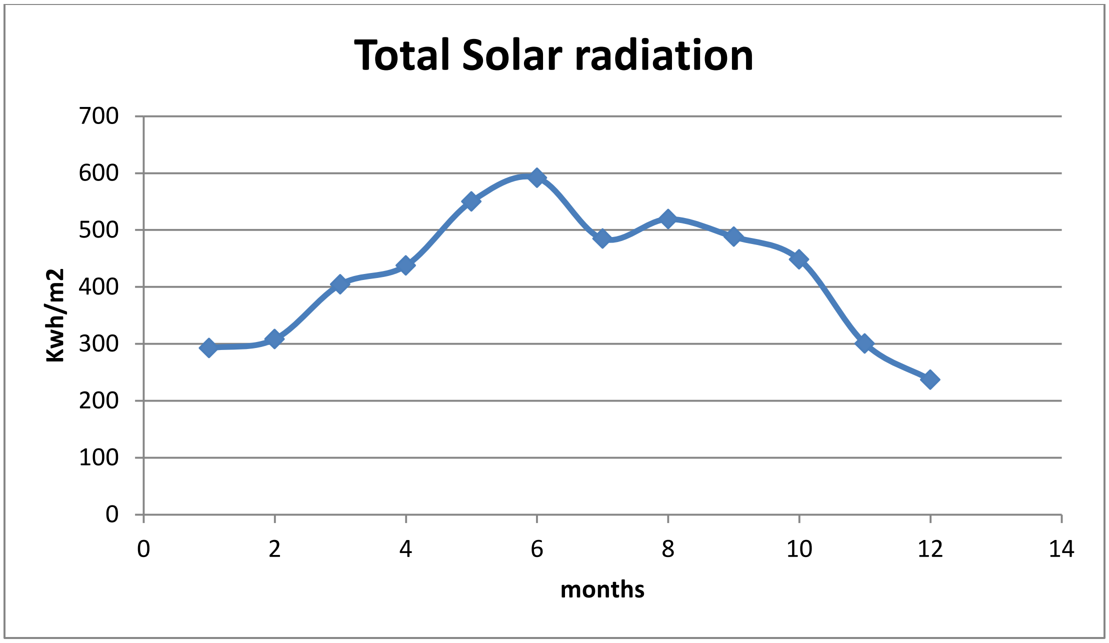

Figure 8: Total Solar radiation per month

Figure 7 and Figure 8 illustrates Qatar’s total radiation that was collected for a whole year. It is noticed from both graphs that solar radiation is highest in month of June and lowest in December.

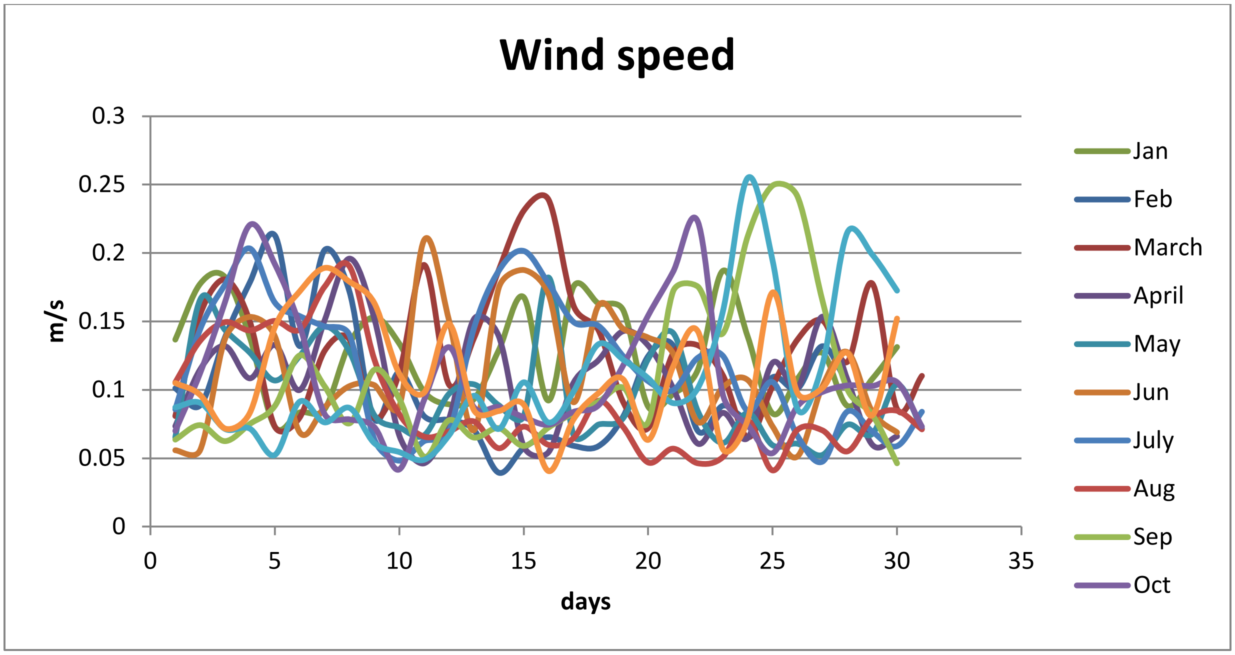

Figure 9: collected daily wind speed at height 10

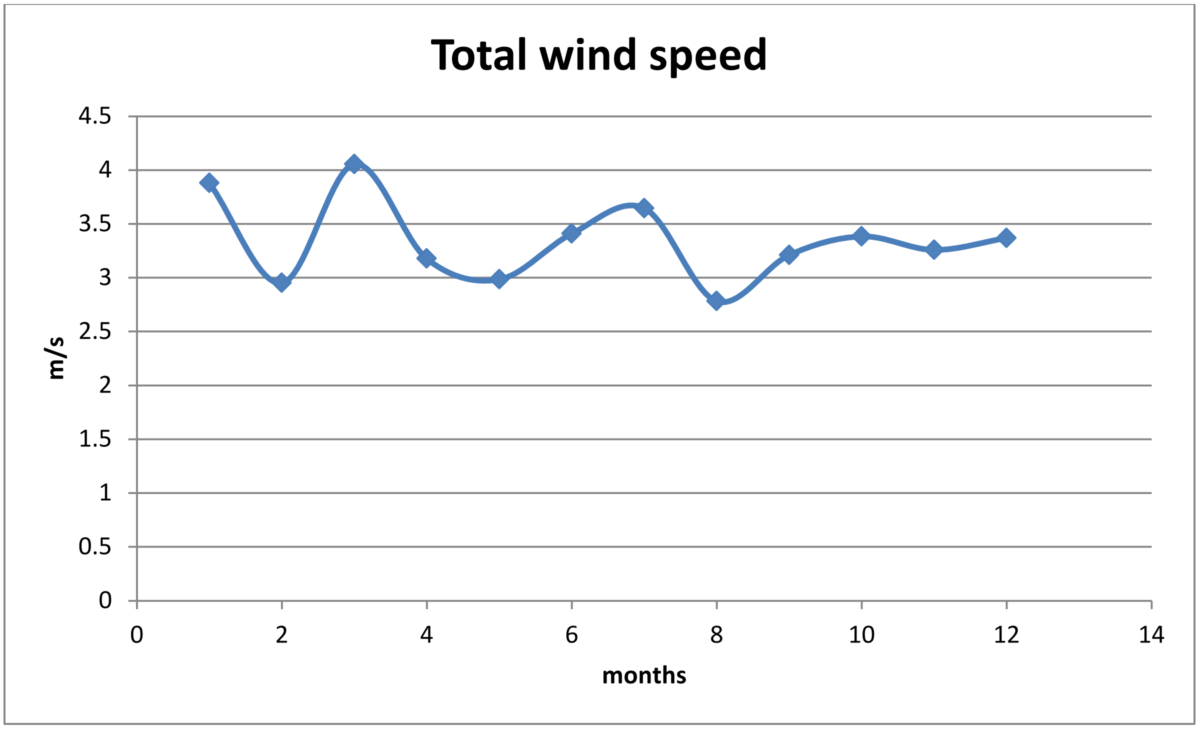

Figure 10: total wind speed per month

Figure 9 and Figure 10 shows Qatar's wind speed in a year. It is presented that march have the highest total speed with a bout 4m/s. January, November and December are considered having high wind speed as well.

4.2. Components specifications

The study was conducted on components that were recommended by Kahramaa and Municipality and Urban Planning. These specifications are shown in Table 4.

Table 4 specifications of components used in study

Component	Technical specifications	Power	Area
PV panel	SHARP, polycrystalline solar panel, NDL235Q1 model	0.235 KW	1.63 m2
Wind turbine	AEOLOS vertical-axis wind turbine, Aeolos-V1 KW model. Cut-in, rated and cut-off speeds of 1.5, 10, 25 m/s, respectively	1 KW	3.14 m2
Waste Boiler	From Keppel Seghers company	Burn 21 tons of waste per hour	NA

4.3. Mathematical model

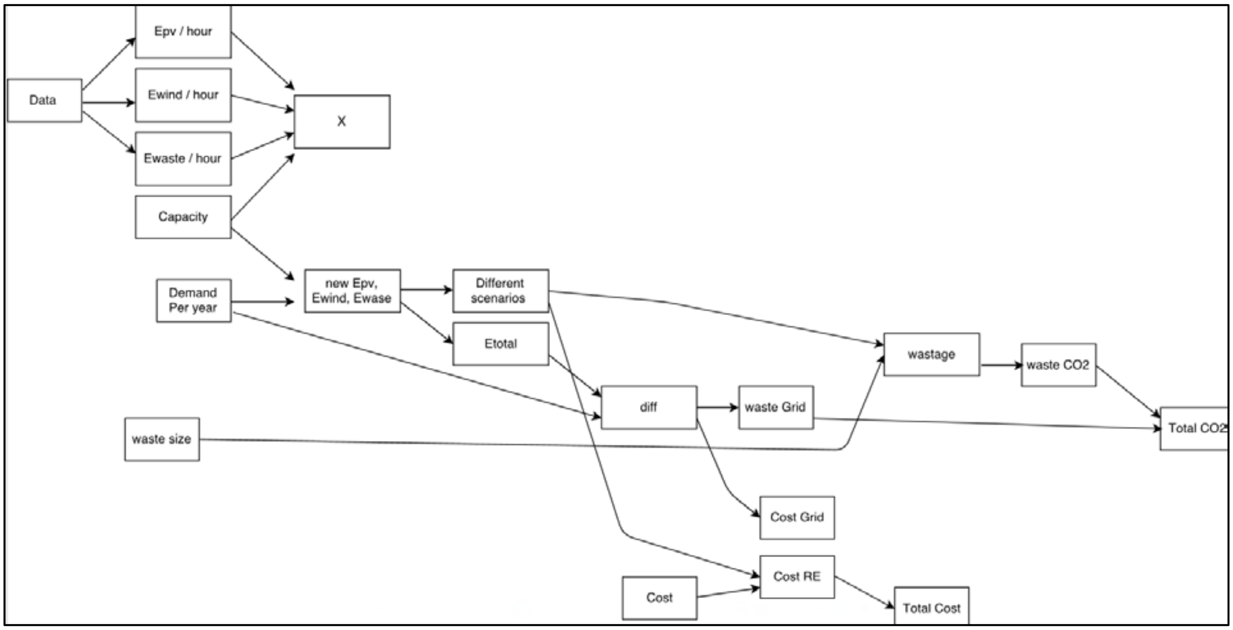

Figure 11: mathematical model of the system

The mathematical model was designed in a Matlab/Simulink file. Where the raw data was used in computation of supplied Energy of each component per hour (Figure 12 to Figure 15). These energies where then entered to a new computation in a code within Matlab to meet constraints. The output of the Matlab code (Appendix A) were different scenarios of different designs and total Energy that each design can Supply. Then in a spread sheet the Cost of each design and CO2 emission of each design were calculated.

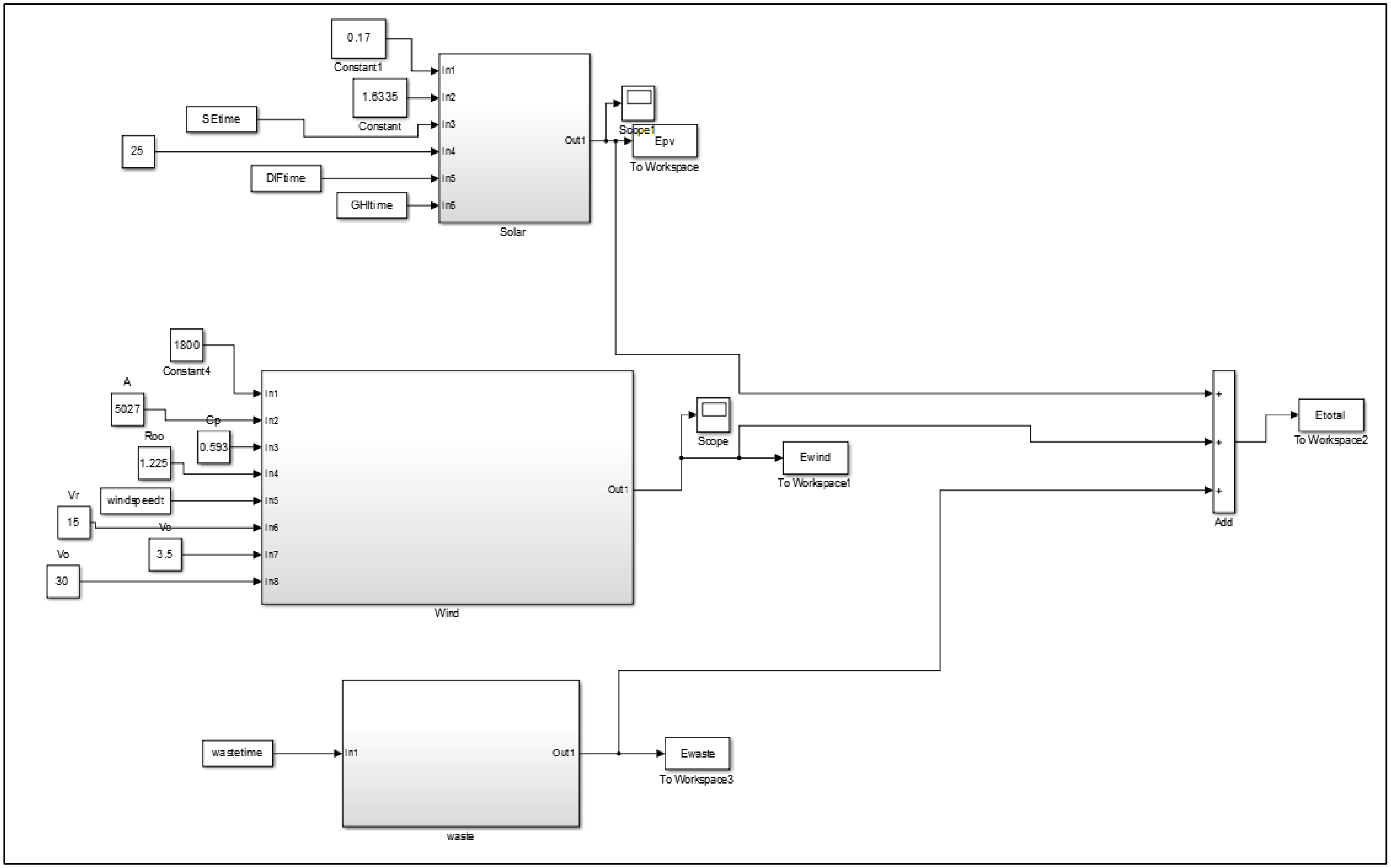

Figure 12: design of hybrid renewable energy in Matlab/Simulink

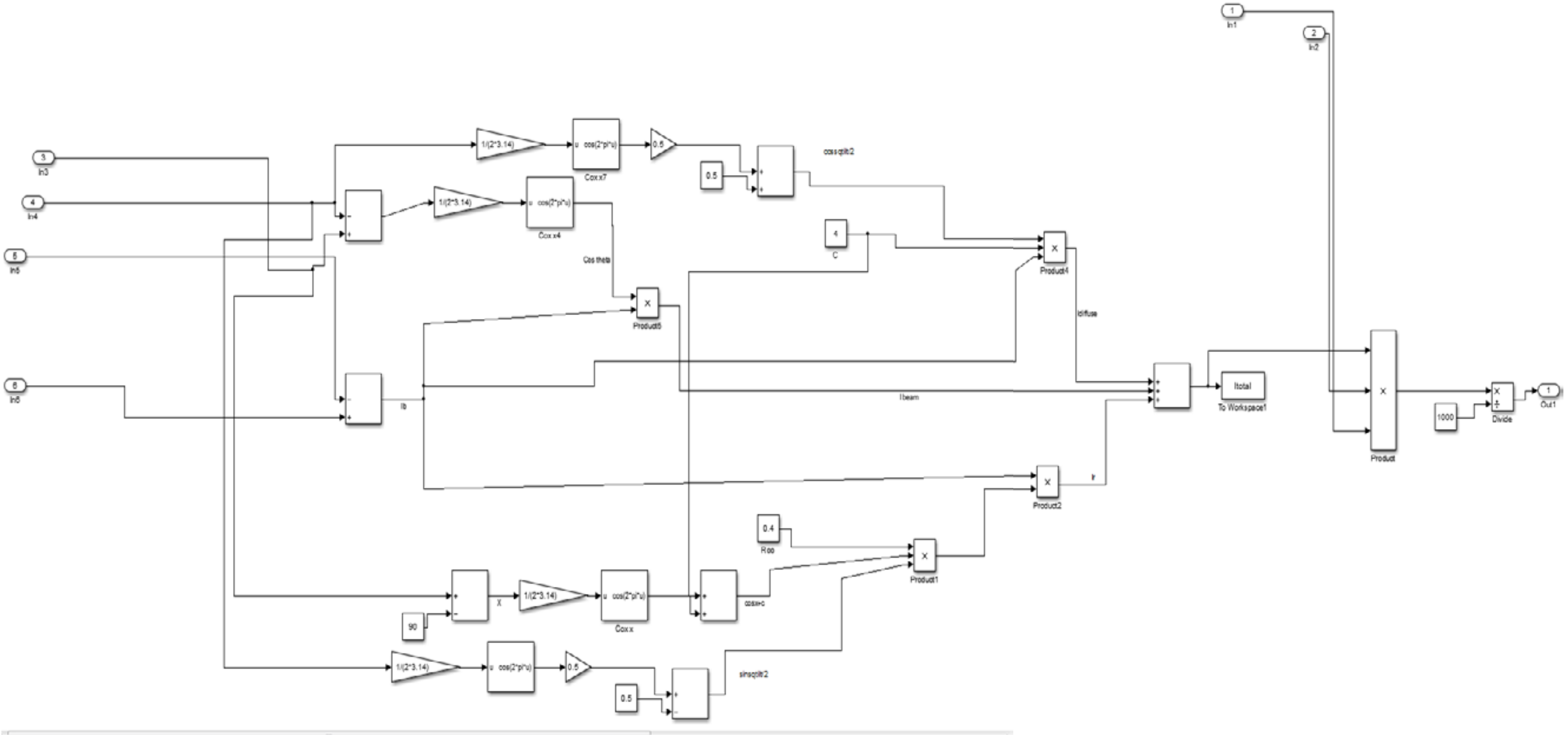

Figure 13: detailed design of PV panel model in Matlab/Simulink

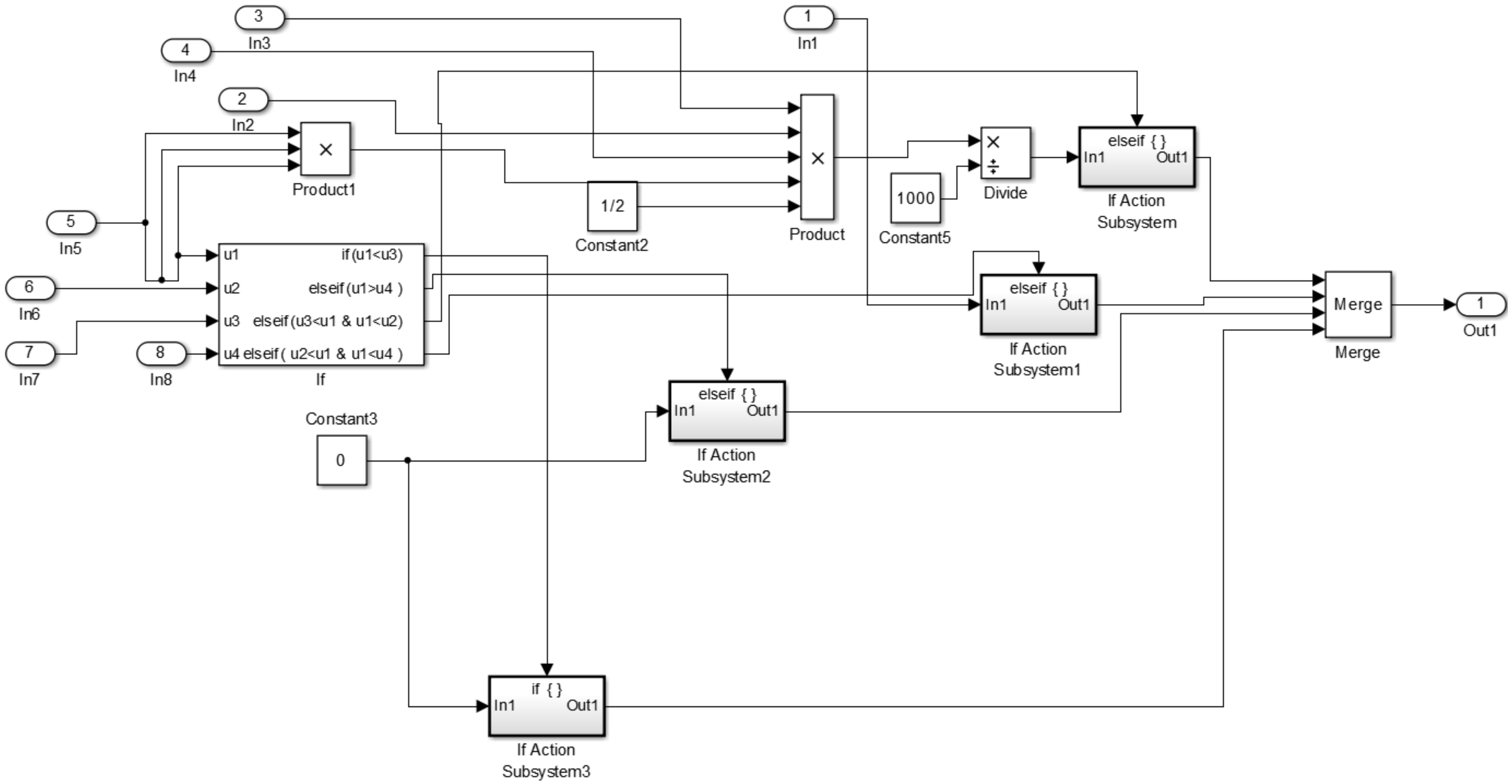

Figure 14:detailed design of wind turbine model in Matlab/Simulink

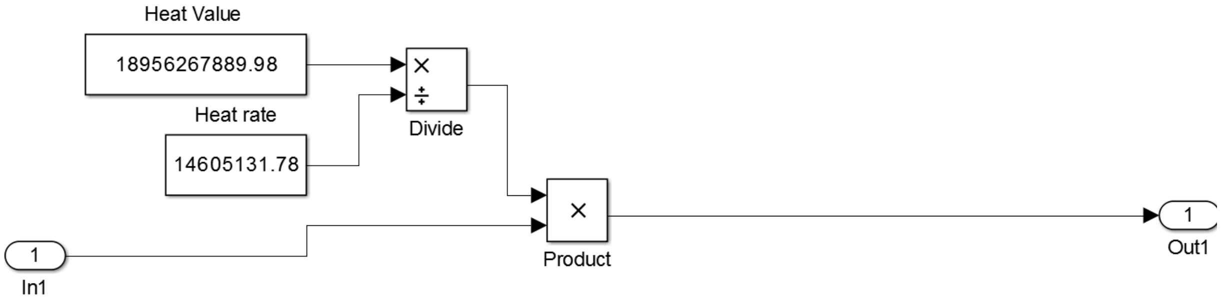

Figure 15: detailed design of waste boiler model in Matlab/Simulink

Chapter 5 - Results Analysis

In order to validate the model each component is considered to be installed in an individual test case scenario and the resulting supply data of the model is evaluated.

The model is being run with raw data of the following:

Area of PV module , Efficiency of module and total sun radiation.

The data were used as inputs in a mathematical Simulink model, The results of the mathematical model, i.e: E_{PV}, E_{wind}, E_{waste}; are then used as input to the matlab code (Appendix A) to compute different designs of the system. After that total cost and total CO_2 emissions were calculated using excel.

The code was run for all cases from 0% of the system feed from renewable energy to using renewable energy as 100%. 132,651 designs we suggested with different combinations.

The system was computed by forcing the system to use 10% of the system's energy from renewable energy sources, 15% of the system's energy from renewable energy sources and 50% of the system's energy from renewable sources. All of these cases are described in this chapter.

1. the system using 10% from Renewable energy sources

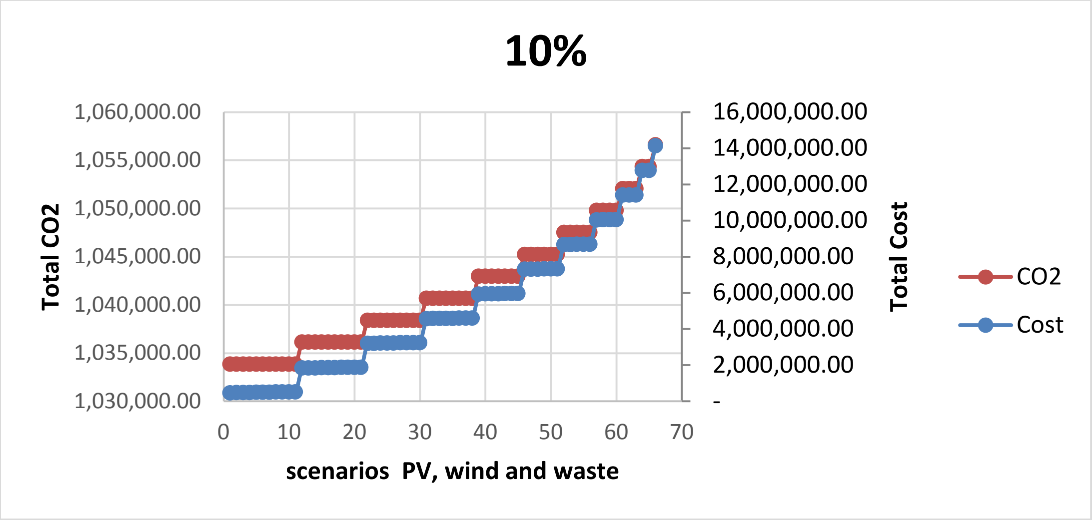

Figure 16: 66 Designs, RE is 10% of the system

Figure 16 shows the results of the system being forced to used 10% of the system from renewable energy sources. The results shows 66 different designs with different costs and different CO2 emissions. The graph shows an increase in cost and CO2. While adding waste boiler to the system amount of CO2 emission is increasing due to burning of material. This shows that adding waste boiler to the system can have negative impact to the environment.

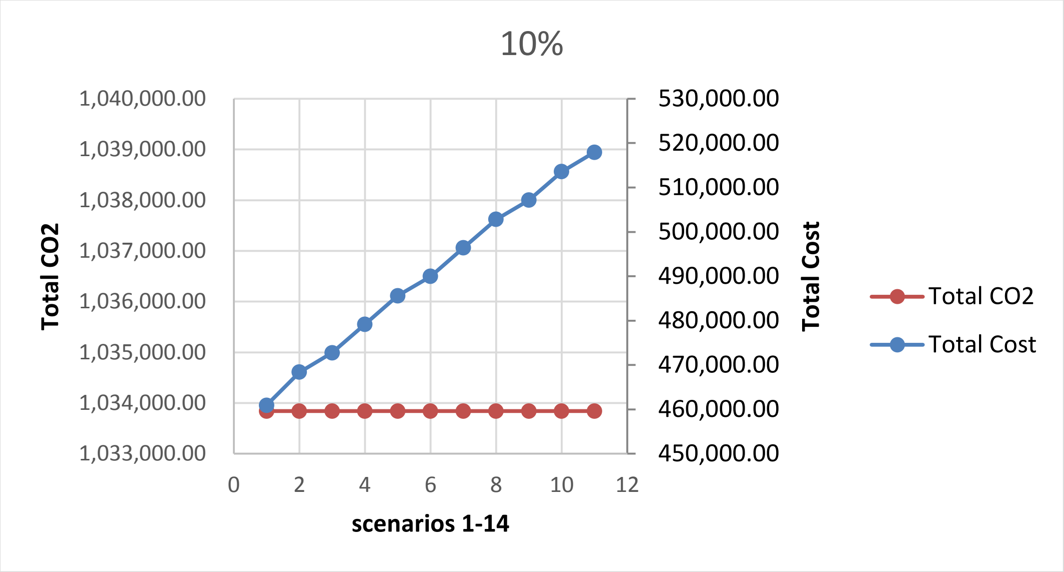

Figure 17: 11 Designs, RE is 10% of the system

Figure 17 shows only 11 designs of systems. These 11 designs shared using only PV and wind turbines as source of Energy in addition to the grid. The total CO2 emissions are from Grid. The cost is maximizing when minimizing wind turbines and adding PV panels.

Table 5: scenarios 1-11 where RE is 10% of the system

scen	PV	Wind	Waste	% sum	# PV	# wind	# waste	Cost ($)	CO2
1	0	10	0	10	0	24	0	460,904.25	1,033,840.63
2	1	9	0	10	11	22	0	468,390.24	1,033,840.63
3	2	8	0	10	21	19	0	472,738.69	1,033,840.63
4	3	7	0	10	31	17	0	479,166.14	1,033,840.63
5	4	6	0	10	41	15	0	485,593.59	1,033,840.63
6	5	5	0	10	51	12	0	489,942.04	1,033,840.63
7	6	4	0	10	61	10	0	496,369.49	1,033,840.63
8	7	3	0	10	71	8	0	502,796.94	1,033,840.63
9	8	2	0	10	81	5	0	507,145.39	1,033,840.63
10	9	1	0	10	91	3	0	513,572.84	1,033,840.63
11	10	0	0	10	101	0	0	517,921.29	1,033,840.63

Table 5 demonstrate the no waste designs with number of PV panels and wind turbines, it is illustrated that the best scenario considering the lowest cost is scenario 1 where PV is 0% of the system, wind is 10% of the system and waste is 0% of the system. Which means the design is using 24 wind turbines in addition to the grid with total of 1,033,840.63 tons of CO2.

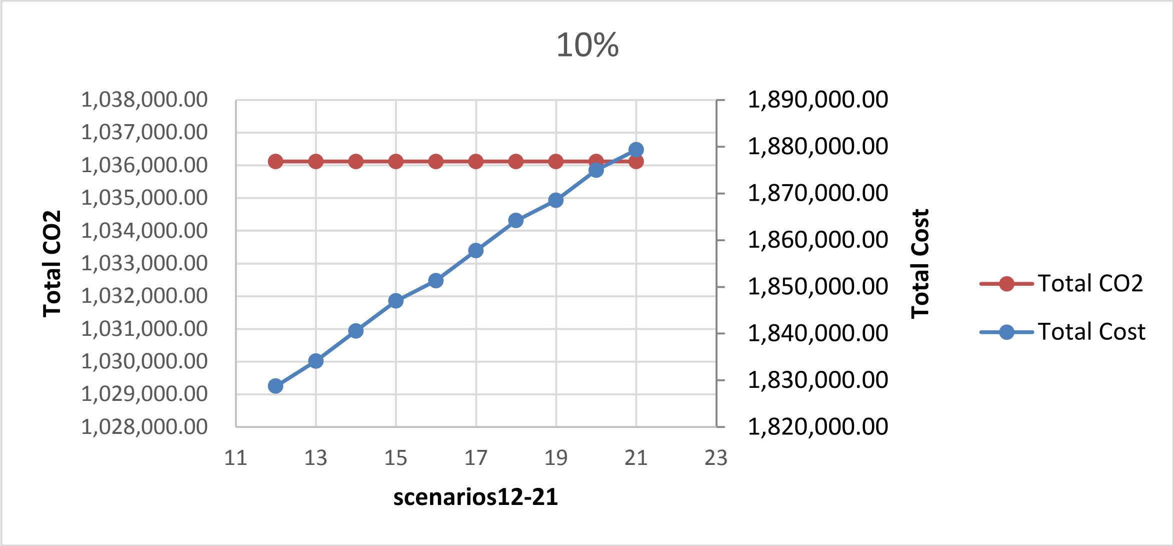

Figure 18: 10 Designs, RE is 10% of the system

In Figure 12 waste boilers are introduced to the system where CO2 emissions maximize to 1,036,117.05 tons. Costs of designs in Figure 18 are higher than costs of those in Figure 17 because of this addition.

Table 6: scenarios 12-21 where RE is 10% of the system

scen	PV	Wind	Waste	% sum	# PV	# wind	# waste	Cost ($)	CO2
12	0	9	1	10	0	21	237	1,828,721.8	1,036,117.05
13	1	8	1	10	11	19	237	1,834,128.8	1,036,117.05
14	2	7	1	10	21	17	237	1,840,556.2	1,036,117.05
15	3	6	1	10	31	15	237	1,846,983.7	1,036,117.05
16	4	5	1	10	41	12	237	1,851,332.1	1,036,117.05
17	5	4	1	10	51	10	237	1,857,759.6	1,036,117.05
18	6	3	1	10	61	8	237	1,864,187.0	1,036,117.05
19	7	2	1	10	71	5	237	1,868,535.5	1,036,117.05
20	8	1	1	10	81	3	237	1,874,962.9	1,036,117.05
21	9	0	1	10	91	0	237	1,879,311.4	1,036,117.05

Table 6 shows the 10 designs of the system with only 1% of it from waste boiler and 9% from PV panel and wind turbine. From the table one can tell the best Scenario considering lowest cost is scenario number 12 which is 0% from PV panel, 9% from wind turbine and 1% from waste boilers. 22 wind turbines shall be 9% of the system and 237 waste boilers are 1% of the system.

2. The system using 15% from Renewable energy sources

Then the system was forced to use 15% of the energy from renewable energy. Forcing the system to do so 136 designs where produced as shown in Figure 19. In the below Figure 19 different amount of CO2 emissions are shown as adding waste boilers is shown form 0% till 15%.

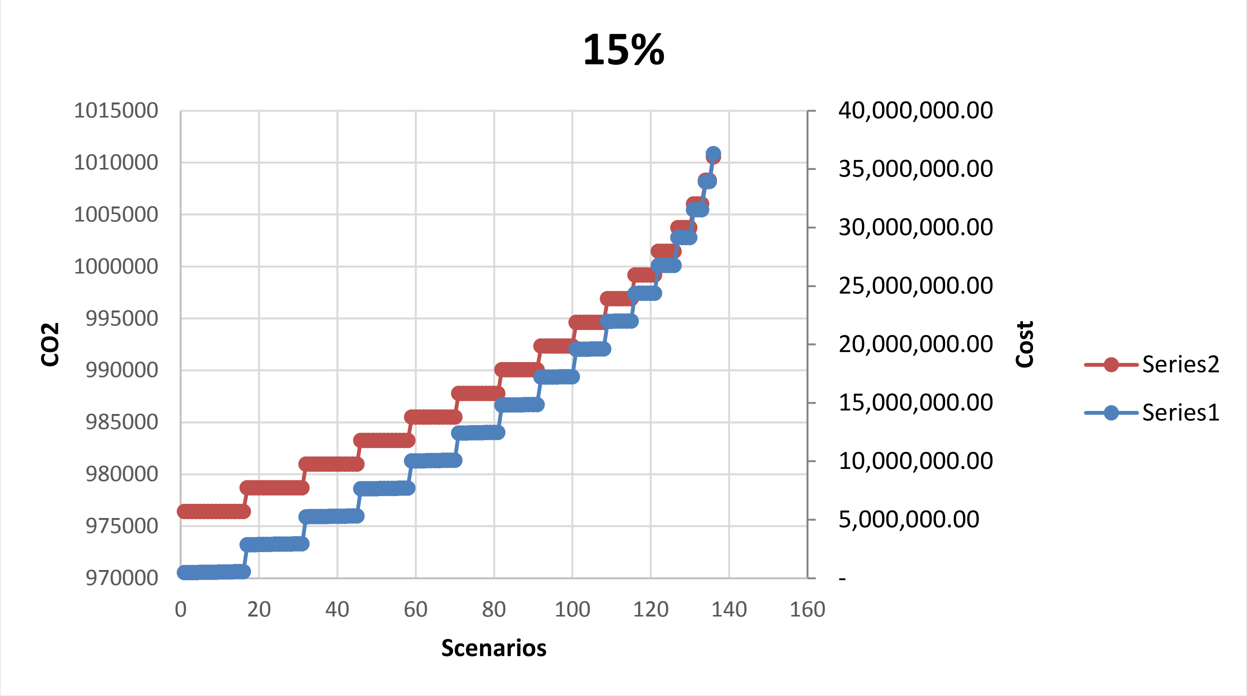

Figure 19: 136 Designs, RE is 15% of system

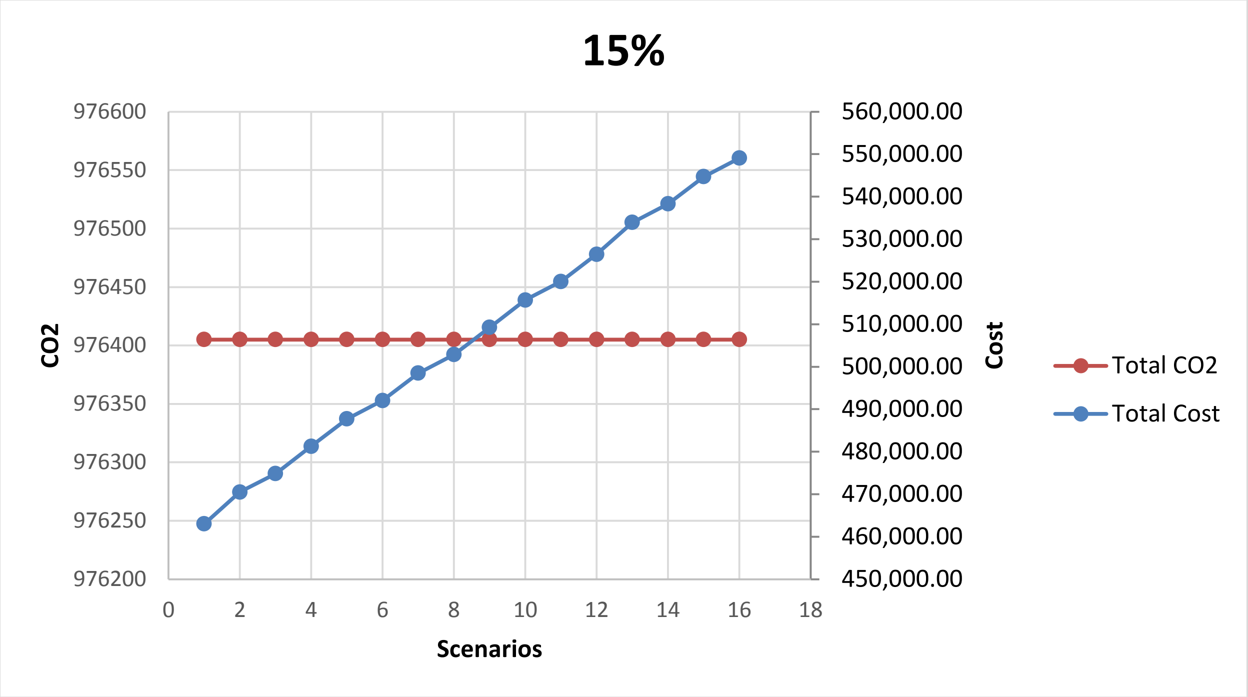

Figure 20: 16 Designs, RE is 15% of the system

In Figure 20 the system is forced to use renewable energy sources as 15% of the system. With 0% of waste boilers is introduced, the model compute 16 design as shown above.

Table 7: scenarios 1-16, RE is 15% of the system

scen	PV	Wind	Waste	% sum	# PV	# wind	# waste	Cost ($)	CO2
1	0	15	0	15	0	36	0	463,018.37	976405.037
2	1	14	0	15	11	34	0	470,504.36	976405.037
3	2	13	0	15	21	31	0	474,852.82	976405.037
4	3	12	0	15	31	29	0	481,280.26	976405.037
5	4	11	0	15	41	27	0	487,707.71	976405.037
6	5	10	0	15	51	24	0	492,056.17	976405.037
7	6	9	0	15	61	22	0	498,483.61	976405.037
8	7	8	0	15	71	19	0	502,832.07	976405.037
9	8	7	0	15	81	17	0	509,259.51	976405.037
10	9	6	0	15	91	15	0	515,686.96	976405.037
11	10	5	0	15	101	12	0	520,035.42	976405.037
12	11	4	0	15	111	10	0	526,462.86	976405.037
13	12	3	0	15	121	8	0	533,948.85	976405.037
14	13	2	0	15	132	5	0	538,297.31	976405.037

15	14	1	0	15	142	3	0	544,724.76	976405.037
16	15	0	0	15	152	0	0	549,073.21	976405.037

The best design considering the lowest cost for the case where the system is feeding 15% from renewable energy is using wind turbines only as shown in Table 7.

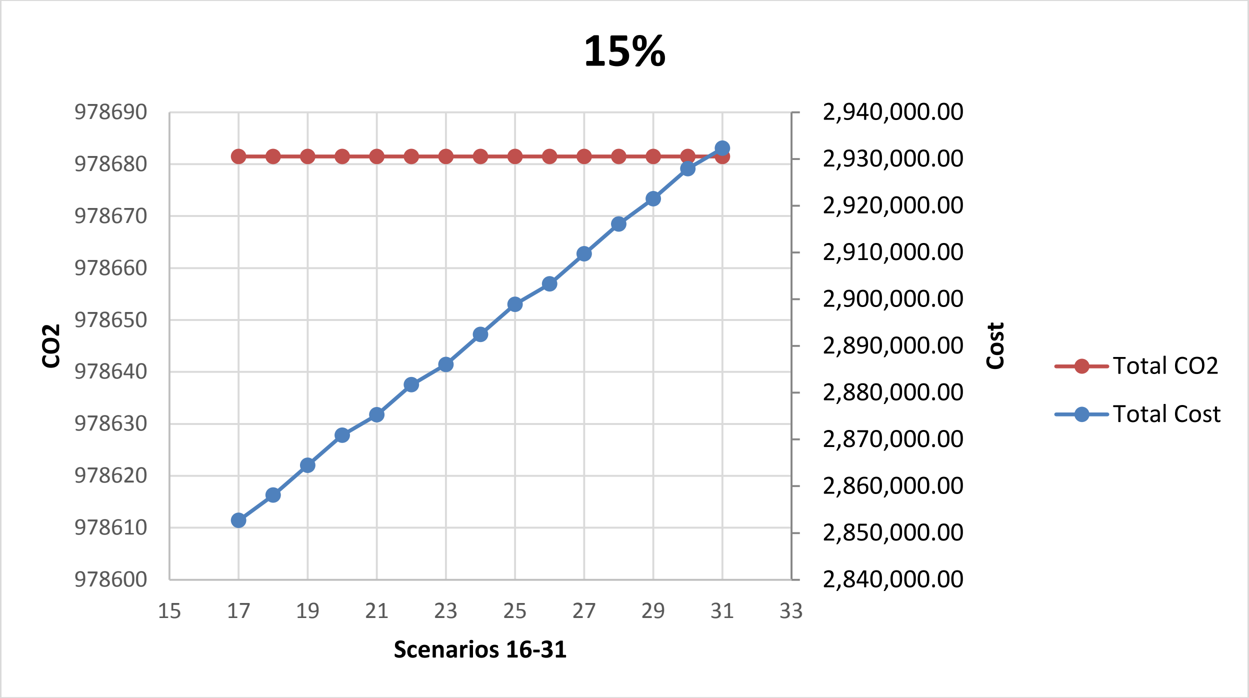

Figure 21: 15 scenarios, RE is 15% of the system

Figure 21 illustrated the 15 scenarios where waste is introduced as a source. CO2 is shown as conastant as for all these 15 scenarios waste energy is only 1%.

Table 8: scenarios 17-31, RE is 15% of the system

sce	PV	Wind	Waste	% sum	# PV	# wind	# waste	Cost ($)	CO2
17	0	14	1	15	0	34	237	2,852,641.5	978681.4
18	1	13	1	15	11	31	237	2,858,048.5	978681.4
19	2	12	1	15	21	29	237	2,864,475.9	978681.4
20	3	11	1	15	31	27	237	2,870,903.3	978681.4
21	4	10	1	15	41	24	237	2,875,251.8	978681.4
22	5	9	1	15	51	22	237	2,881,679.2	978681.4
23	6	8	1	15	61	19	237	2,886,027.7	978681.4
24	7	7	1	15	71	17	237	2,892,455.1	978681.4
25	8	6	1	15	81	15	237	2,898,882.6	978681.4
26	9	5	1	15	91	12	237	2,903,231.0	978681.4
27	10	4	1	15	101	10	237	2,909,658.5	978681.4
28	11	3	1	15	111	8	237	2,916,085.9	978681.4
29	12	2	1	15	122	5	237	2,921,492.9	978681.4
30	13	1	1	15	132	3	237	2,927,920.4	978681.4
31	14	0	1	15	142	0	237	2,932,268.8	978681.4

As the Table 8 is showing, the Best design considering the lowest cost is using PV energy as 0%, wind energy as 14% and waste energy as 1%

3. the system using 50% from Renewable energy sources

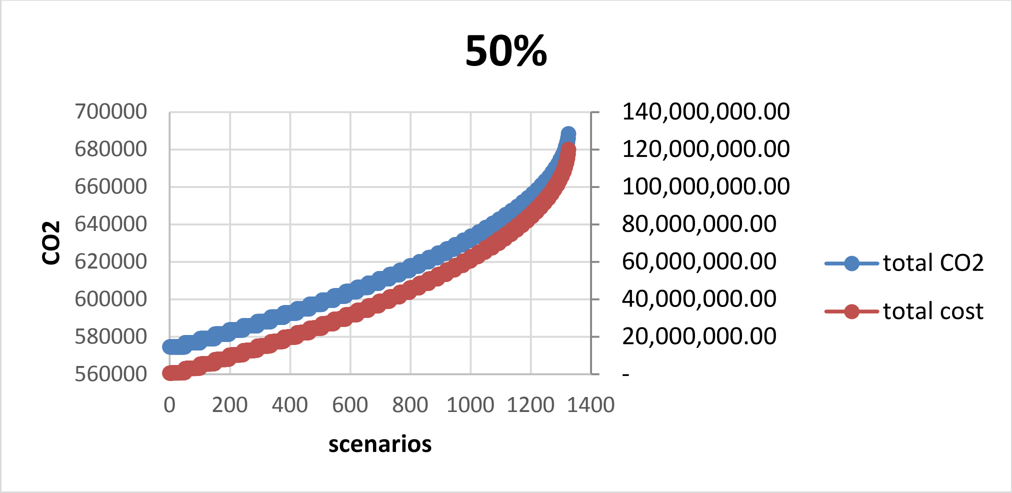

Figure 22: 1326 Designs, RE is 50% of the system

When the model being run with having 50% of energy form renewable sources, 1326 designs of systems are shown as in Figure 22. Different CO2 emissions and different total cost are illustrated.

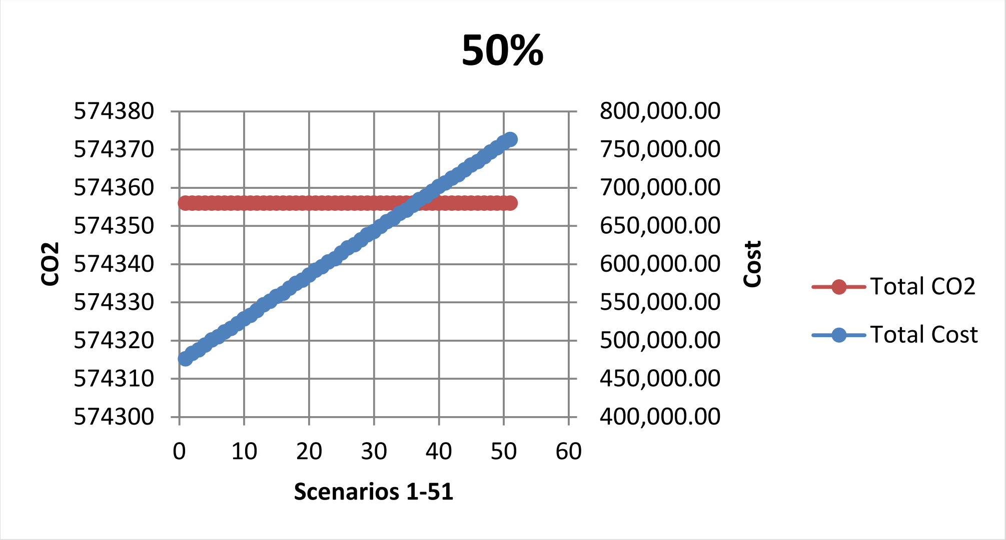

Figure 23: 51 Designs, RE is 50% of the system

Figure 23 shows the 51 designs with no energy from waste source. It is clear that different combination have different costs, whenever PV panel is added cost is going higher. The Best scenario forcing the system to use 50% of the energy from renewable sources is from wind energy only.

Table 9 Summary of optimal scenario for different percentage of Renewable energy in a system

		Scenario			Cost	CO2
		PV	wind	waste		
10%	No waste	0 (0%)	24 (10%)	0 (0%)	460,904.25	1,033,840.63
	No waste Forced to use at least two	0 (1%)	0 (9%)	0 (0%)	468,390.24	1,033,840.63
	Forced to use at least two	0%	9%	1%	1,828,721.83	1,036,117.05
	Forced to use all	1%	8%	1%	1,834,128.83	1,036,117.05
15%	No waste	0 (0%)	24 (15%)	0 (0%)	463,018.37	976,405.037
	No waste Forced to use at least two	0 (1%)	0 (14%)	0 (0%)	470,504.36	976,405.037
	Forced to use at least two	0%	14%	1%	2,852,641.50	978,681.46
	Forced to use all	1%	13%	1%	2,858,048.50	978,681.46
50%	No waste	0%	50%	0%	475,738.24	574,355.90
	No waste Forced to use at least two	1%	49%	0%	483,224.24	574,355.904
	Forced to use at least two	0%	49%	1%	2,865,361.37	576,632.3
	Forced to use all	1%	48%	1%	2,870,768.37	576,632.327

Table 9 summing up different scenarios discussed in this chapter. It is the decision maker call to define the optimal solution for the system to be used. If the case was to use renewable energy ignoring the cost it is better to maximize the percentage of renewable energy sources in the system where CO2 emission will minimize. The total demand per year for the building being studied is 2.0758 MW and the CO2 emission from this is 1,148,711.81 ton.

One solution in case the decision maker want to minimize CO2 emission but want to save cost as well is to force the system to use at least two source but with no waste boiler. As for using 15% of the system from renewable energy sourced CO2 emission is reduced by 15% and cost is increased by 3 % only.

Chapter 6 - Conclusion and Future work

6.1 Conclusion

Qatar is aiming to protect its natural environment and there is a challenge to achieve this vision with speedy growth of electricity demand within the nation. With the growth of the nation, number of facilities are increasing and emissions are increasing. As shown in this study the solution is to have an approach to use hybrid renewable energy system, since it is tough to have one source of renewable energy through the year because of fluctuation.

In this work real data were used in a heuristic approach of designing a hybrid renewable energy system. The system consist of mainly 3 components, PV panels, wind turbines and waste boilers in addition to the connection of the grid. The actual solar irradiation, wind speed and wastage size are used in the simulation model. The system was designed to find optimal investment decisions. The approach focuses mainly on reducing cost and CO2 emission while maintaining the function. The study assures a variety of designs can be implemented. This gives the decision makers the possibility of deciding the best configuration based on aspect rather than cost and CO2 emissions.

The case study results show that adding waste boiler under the chosen conditions with have a high risk of pollution which conflict with the aim of this study. Waste boilers showed high amount of CO2 emissions. Wind turbines and PV panels showed reasonable results but cannot provide the demand of the studied building, meaning the need of electricity grid still exist.

Concluding, based on the objective of the study, the basis of an optimization method was developed, which aims to minimize net present cost and CO2 emissions of a building. The approach was dependent on the charactristic of components provided by government authorities in Qatar.

6.2 Future work

Due to limited time frame, only one type of each component was studied. It is further recommended to apply this work with different types and models of PV panels, wind turbines and waste boilers. This will allow a researcher to comapre different combinations of hybrid renewable.

Future development of this work will consider the following

- introducing other sources of renewable energy sources.
- Storage devices shall be introduced as well.
- The study study shall be done with other methodology to compare results of each method.
- CO2 emissions of PV panels and wind turbines manefacturing.

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Appendix A - Matlab Code

```
load datajan2017.mat
Ewaste=evalin('base','Ewaste');
Demandperyear=2075800;
percRE=100;
percDemand=Demandperyear.*percRE/100;
%%oldCpv=3605;
Cpv=847.111;
COMpv=8.47111;
Cgrid=0.22; %%0.2 per KW
Cwind=1708.788;
COMwind=34.17576;
Cwaste=411032; %%
COMwaste= 44326; %%$/year

%CRF:recovery factor
intrest_rate =0.1; %intereset rate Assume 0.4
T=20; %projectlifetim
CRF = [(intrest_rate*(1+intrest_rate)^T)/((1+intrest_rate)^T-1)];
%salvage value for pv,wind
%Spv=512.6364;
Spv=901.1819149;
Sw=512.6364;
S=(1.04/(1+intrest_rate).^(20));
Crepwaste=2216.3;
ywaste=1; %no. of replacment of each component
nwaste= 1:ywaste;
Lwaste= 15; % lifetime of each component
Kwaste= sum(1./(1+intrest_rate).^(Lwaste*nwaste));
%mysize=8760;
mysize=8760;
time=(0:8759)';
%%PV size
PVcapacity=0.235;
Epvzero=(Epv==0).*0;
Epvrate=(Epv/PVcapacity);
Epvup=(Epv>0);
Epvlower=(Epv<PVcapacity);
Epvbetween=((Epvup & Epvlower).*1);
Epvupper=(Epv>=PVcapacity).*Epvrate;

PVmodule=Epvzero+ Epvbetween+ ceil(Epvupper);
%dataone=ones(mySize,1);
%PVmodule=(PVmodule==0)+PVmodule;


%PVmodule=(Epvzero.*0) + ((Epvlower & Epvup).*1) + ceil(Epvupper.*Epvrate);
modulesize=timeseries(PVmodule,time);
l=modulesize*PVcapacity;
%l=modulesize;
l=l.Data;
l=sum(l);
%wind size
```

```
Wcapacity=1;
%Ewind.Data=Wcapacity*rand(mySize,1);
windturbineszero=(Ewind==0).*0;
turbinerate=(Ewind./Wcapacity);
turbineup=Ewind>0;
turbinelower=Ewind<Wcapacity;
turbinebetween=((turbineup & turbinelower).*1);
turbineupper=(Ewind>=Wcapacity).*turbinerate;
windturbine= windturbineszero+ turbinebetween + ceil (turbineupper);
%dataone=ones(mySize,1);
windmodule=(windturbine==0)+windturbine;

windturbines1=timeseries(windmodule,time)
%windturbines1=timeseries(windturbines,time)
y=windturbines1*Wcapacity;
%y=windturbines1;
y=y.Data;
ym=sum(y);

Wastecapacity=0.01;

boilerzero=(Ewaste==0).*0;
boilerrate=(Ewaste./Wastecapacity);
boilerup=(Ewaste>0);
boilerlower=(Ewaste<Wastecapacity);
boilerbetween=((boilerup & boilerlower).*1);
boilerupper=(Ewaste>=Wastecapacity).*boilerrate;

boilermodule=boilerzero+ boilerbetween+ ceil(boilerupper);
%dataone=ones(mySize,1);
boilermodule=(boilermodule==0)+boilermodule;

boilermodule1=timeseries(boilermodule,time)
%windturbines1=timeseries(windturbines,time)
z=boilermodule1*Wastecapacity;
%y=windturbines1;
z=z.Data;
z=sum(z);

x=[l ym z];

%i=percRE/(PVcapacity+Wcapacity+Wastecapacity);
i=percRE;
j=percRE;
k=percRE;

obj=(Cpv+(COMpv/CRF)+(Spv*S))*x(:,1)+(Cwind+(COMwind/CRF)+(Sw*S))*x(:,2)+(Cwa
ste+(COMwaste/CRF)+(Crepwaste*Kwaste))*x(:,3);
%obj=(Cpv+(COMpv/CRF)+(Spv*S))*l+(Cwind+(COMwind/CRF)+(Sw*S))*ym+(Cwaste+(COM
waste/CRF)+(Crepwaste*Kwaste))*z;



for i=0:100
           for k=0:100
            for j=0:100
```

```
            ip=i/100;
            jp=j/100;
            kp=k/100;
             %%temp=(i-1)*11*11 + (j-1)*11 +k;
             %%temp=(i)*10*10 + (j)*10 +k;
             temp= j;

        newPV(i+1,:)=[(ip*Demandperyear)/(PVcapacity*8760) i] ;
        %newPV(i+1,:)=[0 i] ;
        newwind(j+1,:)=[(jp*Demandperyear)/(Wcapacity*8760) j];
       % newwind(j+1,:)=[0 j];
        newwaste(k+1,:)=[(kp*Demandperyear)/(Wastecapacity*8760) k];
        %newwaste(k+1,:)=[0 k];


        end
    end
end

                for m=1:101
                for n=1:101
                for o=1:101
         temp1=(m-1)*101*101 + (n-1)*101 +o;
         %temp1=(m)*11;
         max_sum=m+n+o;
         summ=(m-1)+(n-1)+(o-1);

         scenperce(temp1,:)=[newPV(m) newwind(n) newwaste(o) summ];
         scen(temp1,:)=[newPV(m) newwind(n) newwaste(o)];

         if max_sum>=101  %% to exclude less than 10%

         scen1(temp1,:)=[newPV(n) newwind(m) newwaste(o)];
         Etotal(temp1,:)=newPV(n)+newwind(m)+newwaste(o);


         end

         end
         end
                end

 sumwaste=481057;
  %%exclude CO2 higher than
  mysize=length(scen1);

       for i=1:mysize
      Etotal(i,:)=Etotal(i,:);
      %Etotal=Etotal';
    demandyearly=Demandperyear*ones(mysize,1);
    diff(i,:)=demandyearly(i,:)-Etotal(i,:);
    wastage(i,:)=sumwaste*scen1(i,[3]);
       end
```

Appendix B – Results 10% only

PV	wind	waste	scen	sce	scen	sum	newPV	newwind	new waste	total Energy	diff	met	wastage	CO2 waste	Cost Grid	Cost per month	PV Cap	wind Cap	waste capital	PV OM	wind OM	waste OM	PV rep	wind replacement	waste replacment	total (no grid)	total cost	gridCO2	total CO2
0	23.69635	0	0	10	0	10	0	207580	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	0.0	41010.912	0	0	6982.98025	0	0	1901.955353	0	49,895.85	460,904.25	1,033,840.63	1,033,840.63
10.08355	21.32671	0	1	9	0	10	20758	186822	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	9318.2	37593.336	0	793.3127	6401.06523	0	1532.445	1743.459074	0	57,381.84	468,390.24	1,033,840.63	1,033,840.63
20.1671	18.95708	0	2	8	0	10	41516	166064	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	17789.3	32466.972	0	1514.506	5528.1927	0	2925.576	1505.714655	0	61,730.29	472,738.69	1,033,840.63	1,033,840.63
30.25066	16.58744	0	3	7	0	10	62274	145306	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	26260.4	29049.396	0	2235.699	4946.27768	0	4318.707	1347.218375	0	68,157.74	479,166.14	1,033,840.63	1,033,840.63
40.33421	14.21781	0	4	6	0	10	83032	124548	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	34731.6	25631.82	0	2956.893	4364.36266	0	5711.839	1188.722096	0	74,585.19	485,593.59	1,033,840.63	1,033,840.63
50.41776	11.84817	0	5	5	0	10	103790	103790	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	43202.7	20505.456	0	3678.086	3491.49013	0	7104.97	950.9776767	0	78,933.64	489,942.04	1,033,840.63	1,033,840.63
60.50131	9.478539	0	6	4	0	10	124548	83032	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	51673.8	17087.88	0	4399.279	2909.5751	0	8498.102	792.4813973	0	85,361.09	496,369.49	1,033,840.63	1,033,840.63
70.58486	7.108904	0	7	3	0	10	145306	62274	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	60144.9	13670.304	0	5120.473	2327.66008	0	9891.233	633.9851178	0	91,788.54	502,796.94	1,033,840.63	1,033,840.63
80.66842	4.739269	0	8	2	0	10	166064	41516	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	68616.0	8543.94	0	5841.666	1454.78755	0	11284.36	396.2406986	0	96,136.99	507,145.39	1,033,840.63	1,033,840.63
90.75197	2.369635	0	9	1	0	10	186822	20758	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	77087.1	5126.364	0	6562.859	872.872531	0	12677.5	237.7444192	0	102,564.44	513,572.84	1,033,840.63	1,033,840.63
100.8355	0	0	10	0	0	10	207580	0	0	207580	(1,868,220.00)	No	0	0	411008.4	34250.7	85558.2	0	0	7284.053	0	0	14070.63	0	0	106,912.89	517,921.29	1,033,840.63	1,033,840.63
0	21.32671	236.9635	0	9	1	10	0	186822	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	0.0	37593.336	1094940	0	6401.06523	275418.0431	0	1743.459074	1617.525	1,417,713.43	1,828,721.83	1,033,840.63	1,036,117.05
10.08355	18.95708	236.9635	1	8	1	10	20758	166064	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	9318.2	32466.972	1094940	793.3127	5528.1927	275418.0431	1532.445	1505.714655	1617.525	1,423,120.43	1,834,128.83	1,033,840.63	1,036,117.05
20.1671	16.58744	236.9635	2	7	1	10	41516	145306	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	17789.3	29049.396	1094940	1514.506	4946.27768	275418.0431	2925.576	1347.218375	1617.525	1,429,547.87	1,840,556.27	1,033,840.63	1,036,117.05
30.25066	14.21781	236.9635	3	6	1	10	62274	124548	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	26260.4	25631.82	1094940	2235.699	4364.36266	275418.0431	4318.707	1188.722096	1617.525	1,435,975.32	1,846,983.72	1,033,840.63	1,036,117.05
40.33421	11.84817	236.9635	4	5	1	10	83032	103790	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	34731.6	20505.456	1094940	2956.893	3491.49013	275418.0431	5711.839	950.9776767	1617.525	1,440,323.77	1,851,332.17	1,033,840.63	1,036,117.05
50.41776	9.478539	236.9635	5	4	1	10	103790	83032	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	43202.7	17087.88	1094940	3678.086	2909.5751	275418.0431	7104.97	792.4813973	1617.525	1,446,751.22	1,857,759.62	1,033,840.63	1,036,117.05
60.50131	7.108904	236.9635	6	3	1	10	124548	62274	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	51673.8	13670.304	1094940	4399.279	2327.66008	275418.0431	8498.102	633.9851178	1617.525	1,453,178.67	1,864,187.07	1,033,840.63	1,036,117.05
70.58486	4.739269	236.9635	7	2	1	10	145306	41516	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	60144.9	8543.94	1094940	5120.473	1454.78755	275418.0431	9891.233	396.2406986	1617.525	1,457,527.12	1,868,535.52	1,033,840.63	1,036,117.05
80.66842	2.369635	236.9635	8	1	1	10	166064	20758	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	68616.0	5126.364	1094940	5841.666	872.872531	275418.0431	11284.36	237.7444192	1617.525	1,463,954.57	1,874,962.97	1,033,840.63	1,036,117.05
90.75197	0	236.9635	9	0	1	10	186822	0	20758	207580	(1,868,220.00)	No	4976.2329	2276.422829	411008.4	34250.7	77087.1	0	1094940	6562.859	0	275418.0431	12677.5	0	1617.525	1,468,303.02	1,879,311.42	1,033,840.63	1,036,117.05
0	18.95708	473.9269	0	8	2	10	0	166064	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	0.0	32466.972	2189880	0	5528.1927	550836.0862	0	1505.714655	3235.05	2,783,452.02	3,194,460.42	1,033,840.63	1,038,393.47
10.08355	16.58744	473.9269	1	7	2	10	20758	145306	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	9318.2	29049.396	2189880	793.3127	4946.27768	550836.0862	1532.445	1347.218375	3235.05	2,790,938.01	3,201,946.41	1,033,840.63	1,038,393.47
20.1671	14.21781	473.9269	2	6	2	10	41516	124548	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	17789.3	25631.82	2189880	1514.506	4364.36266	550836.0862	2925.576	1188.722096	3235.05	2,797,365.45	3,208,373.85	1,033,840.63	1,038,393.47
30.25066	11.84817	473.9269	3	5	2	10	62274	103790	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	26260.4	20505.456	2189880	2235.699	3491.49013	550836.0862	4318.707	950.9776767	3235.05	2,801,713.91	3,212,722.31	1,033,840.63	1,038,393.47
40.33421	9.478539	473.9269	4	4	2	10	83032	83032	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	34731.6	17087.88	2189880	2956.893	2909.5751	550836.0862	5711.839	792.4813973	3235.05	2,808,141.36	3,219,149.76	1,033,840.63	1,038,393.47
50.41776	7.108904	473.9269	5	3	2	10	103790	62274	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	43202.7	13670.304	2189880	3678.086	2327.66008	550836.0862	7104.97	633.9851178	3235.05	2,814,568.80	3,225,577.20	1,033,840.63	1,038,393.47
60.50131	4.739269	473.9269	6	2	2	10	124548	41516	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	51673.8	8543.94	2189880	4399.279	1454.78755	550836.0862	8498.102	396.2406986	3235.05	2,818,917.26	3,229,925.66	1,033,840.63	1,038,393.47
70.58486	2.369635	473.9269	7	1	2	10	145306	20758	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	60144.9	5126.364	2189880	5120.473	872.872531	550836.0862	9891.233	237.7444192	3235.05	2,825,344.70	3,236,353.10	1,033,840.63	1,038,393.47
80.66842	0	473.9269	8	0	2	10	166064	0	41516	207580	(1,868,220.00)	No	9952.4658	4552.845657	411008.4	34250.7	68616.0	0	2189880	5841.666	0	550836.0862	11284.36	0	3235.05	2,829,693.16	3,240,701.56	1,033,840.63	1,038,393.47
0	16.58744	710.8904	0	7	3	10	0	145306	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	0.0	29049.396	3284820	0	4946.27768	826254.1293	0	1347.218375	4852.575	4,151,269.60	4,562,278.00	1,033,840.63	1,040,669.90
10.08355	14.21781	710.8904	1	6	3	10	20758	124548	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	9318.2	25631.82	3284820	793.3127	4364.36266	826254.1293	1532.445	1188.722096	4852.575	4,158,755.59	4,569,763.99	1,033,840.63	1,040,669.90
20.1671	11.84817	710.8904	2	5	3	10	41516	103790	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	17789.3	20505.456	3284820	1514.506	3491.49013	826254.1293	2925.576	950.9776767	4852.575	4,163,104.04	4,574,112.44	1,033,840.63	1,040,669.90
30.25066	9.478539	710.8904	3	4	3	10	62274	83032	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	26260.4	17087.88	3284820	2235.699	2909.5751	826254.1293	4318.707	792.4813973	4852.575	4,169,531.49	4,580,539.89	1,033,840.63	1,040,669.90
40.33421	7.108904	710.8904	4	3	3	10	83032	62274	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	34731.6	13670.304	3284820	2956.893	2327.66008	826254.1293	5711.839	633.9851178	4852.575	4,175,958.94	4,586,967.34	1,033,840.63	1,040,669.90
50.41776	4.739269	710.8904	5	2	3	10	103790	41516	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	43202.7	8543.94	3284820	3678.086	1454.78755	826254.1293	7104.97	396.2406986	4852.575	4,180,307.39	4,591,315.79	1,033,840.63	1,040,669.90

60.50131	2.369635	710.8904	6	1	3	10	124548	20758	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	51673.8	5126.364	3284820	4399.279	872.872531	826254.1293	8498.102	237.7444192	4852.575	4,186,734.84	4,597,743.24	1,033,840.63	1,040,669.90
70.58486	0	710.8904	7	0	3	10	145306	0	62274	207580	(1,868,220.00)	No	14928.699	6829.268486	411008.4	34250.7	60144.9	0	3284820	5120.473	0	826254.1293	9891.233	0	4852.575	4,191,083.29	4,602,091.69	1,033,840.63	1,040,669.90
0	14.21781	947.8539	0	6	4	10	0	124548	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	0.0	25631.82	4379760	0	4364.36266	1101672.172	0	1188.722096	6470.1	5,519,087.18	5,930,095.58	1,033,840.63	1,042,946.32
10.08355	11.84817	947.8539	1	5	4	10	20758	103790	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	9318.2	20505.456	4379760	793.3127	3491.49013	1101672.172	1532.445	950.9776767	6470.1	5,524,494.17	5,935,502.57	1,033,840.63	1,042,946.32
20.1671	9.478539	947.8539	2	4	4	10	41516	83032	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	17789.3	17087.88	4379760	1514.506	2909.5751	1101672.172	2925.576	792.4813973	6470.1	5,530,921.62	5,941,930.02	1,033,840.63	1,042,946.32
30.25066	7.108904	947.8539	3	3	4	10	62274	62274	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	26260.4	13670.304	4379760	2235.699	2327.66008	1101672.172	4318.707	633.9851178	6470.1	5,537,349.07	5,948,357.47	1,033,840.63	1,042,946.32
40.33421	4.739269	947.8539	4	2	4	10	83032	41516	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	34731.6	8543.94	4379760	2956.893	1454.78755	1101672.172	5711.839	396.2406986	6470.1	5,541,697.52	5,952,705.92	1,033,840.63	1,042,946.32
50.41776	2.369635	947.8539	5	1	4	10	103790	20758	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	43202.7	5126.364	4379760	3678.086	872.872531	1101672.172	7104.97	237.7444192	6470.1	5,548,124.97	5,959,133.37	1,033,840.63	1,042,946.32
60.50131	0	947.8539	6	0	4	10	124548	0	83032	207580	(1,868,220.00)	No	19904.932	9105.691315	411008.4	34250.7	51673.8	0	4379760	4399.279	0	1101672.172	8498.102	0	6470.1	5,552,473.42	5,963,481.82	1,033,840.63	1,042,946.32
0	11.84817	1184.817	0	5	5	10	0	103790	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	0.0	20505.456	5474700	0	3491.49013	1377090.216	0	950.9776767	8087.625	6,884,825.76	7,295,834.16	1,033,840.63	1,045,222.74
10.08355	9.478539	1184.817	1	4	5	10	20758	83032	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	9318.2	17087.88	5474700	793.3127	2909.5751	1377090.216	1532.445	792.4813973	8087.625	6,892,311.76	7,303,320.16	1,033,840.63	1,045,222.74
20.1671	7.108904	1184.817	2	3	5	10	41516	62274	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	17789.3	13670.304	5474700	1514.506	2327.66008	1377090.216	2925.576	633.9851178	8087.625	6,898,739.20	7,309,747.60	1,033,840.63	1,045,222.74
30.25066	4.739269	1184.817	3	2	5	10	62274	41516	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	26260.4	8543.94	5474700	2235.699	1454.78755	1377090.216	4318.707	396.2406986	8087.625	6,903,087.66	7,314,096.06	1,033,840.63	1,045,222.74
40.33421	2.369635	1184.817	4	1	5	10	83032	20758	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	34731.6	5126.364	5474700	2956.893	872.872531	1377090.216	5711.839	237.7444192	8087.625	6,909,515.10	7,320,523.50	1,033,840.63	1,045,222.74
50.41776	0	1184.817	5	0	5	10	103790	0	103790	207580	(1,868,220.00)	No	24881.164	11382.11414	411008.4	34250.7	43202.7	0	5474700	3678.086	0	1377090.216	7104.97	0	8087.625	6,913,863.56	7,324,871.96	1,033,840.63	1,045,222.74
0	9.478539	1421.781	0	4	6	10	0	83032	124548	207580	(1,868,220.00)	No	29857.397	13658.53697	411008.4	34250.7	0.0	17087.88	6569640	0	2909.5751	1652508.259	0	792.4813973	9705.15	8,252,643.35	8,663,651.75	1,033,840.63	1,047,499.16
10.08355	7.108904	1421.781	1	3	6	10	20758	62274	124548	207580	(1,868,220.00)	No	29857.397	13658.53697	411008.4	34250.7	9318.2	13670.304	6569640	793.3127	2327.66008	1652508.259	1532.445	633.9851178	9705.15	8,260,129.34	8,671,137.74	1,033,840.63	1,047,499.16
20.1671	4.739269	1421.781	2	2	6	10	41516	41516	124548	207580	(1,868,220.00)	No	29857.397	13658.53697	411008.4	34250.7	17789.3	8543.94	6569640	1514.506	1454.78755	1652508.259	2925.576	396.2406986	9705.15	8,264,477.79	8,675,486.19	1,033,840.63	1,047,499.16
30.25066	2.369635	1421.781	3	1	6	10	62274	20758	124548	207580	(1,868,220.00)	No	29857.397	13658.53697	411008.4	34250.7	26260.4	5126.364	6569640	2235.699	872.872531	1652508.259	4318.707	237.7444192	9705.15	8,270,905.24	8,681,913.64	1,033,840.63	1,047,499.16
40.33421	0	1421.781	4	0	6	10	83032	0	124548	207580	(1,868,220.00)	No	29857.397	13658.53697	411008.4	34250.7	34731.6	0	6569640	2956.893	0	1652508.259	5711.839	0	9705.15	8,275,253.69	8,686,262.09	1,033,840.63	1,047,499.16
0	7.108904	1658.744	0	3	7	10	0	62274	145306	207580	(1,868,220.00)	No	34833.63	15934.9598	411008.4	34250.7	0.0	13670.304	7664580	0	2327.66008	1927926.302	0	633.9851178	11322.675	9,620,460.93	10,031,469.33	1,033,840.63	1,049,775.59
10.08355	4.739269	1658.744	1	2	7	10	20758	41516	145306	207580	(1,868,220.00)	No	34833.63	15934.9598	411008.4	34250.7	9318.2	8543.94	7664580	793.3127	1454.78755	1927926.302	1532.445	396.2406986	11322.675	9,625,867.92	10,036,876.32	1,033,840.63	1,049,775.59
20.1671	2.369635	1658.744	2	1	7	10	41516	20758	145306	207580	(1,868,220.00)	No	34833.63	15934.9598	411008.4	34250.7	17789.3	5126.364	7664580	1514.506	872.872531	1927926.302	2925.576	237.7444192	11322.675	9,632,295.37	10,043,303.77	1,033,840.63	1,049,775.59
30.25066	0	1658.744	3	0	7	10	62274	0	145306	207580	(1,868,220.00)	No	34833.63	15934.9598	411008.4	34250.7	26260.4	0	7664580	2235.699	0	1927926.302	4318.707	0	11322.675	9,636,643.82	10,047,652.22	1,033,840.63	1,049,775.59
0	4.739269	1895.708	0	2	8	10	0	41516	166064	207580	(1,868,220.00)	No	39809.863	18211.38263	411008.4	34250.7	0.0	8543.94	8759520	0	1454.78755	2203344.345	0	396.2406986	12940.2	10,986,199.51	11,397,207.91	1,033,840.63	1,052,052.01
10.08355	2.369635	1895.708	1	1	8	10	20758	20758	166064	207580	(1,868,220.00)	No	39809.863	18211.38263	411008.4	34250.7	9318.2	5126.364	8759520	793.3127	872.872531	2203344.345	1532.445	237.7444192	12940.2	10,993,685.50	11,404,693.90	1,033,840.63	1,052,052.01
20.1671	0	1895.708	2	0	8	10	41516	0	166064	207580	(1,868,220.00)	No	39809.863	18211.38263	411008.4	34250.7	17789.3	0	8759520	1514.506	0	2203344.345	2925.576	0	12940.2	10,998,033.96	11,409,042.36	1,033,840.63	1,052,052.01
0	2.369635	2132.671	0	1	9	10	0	20758	186822	207580	(1,868,220.00)	No	44786.096	20487.80546	411008.4	34250.7	0.0	5126.364	9854460	0	872.872531	2478762.388	0	237.7444192	14557.725	12,354,017.09	12,765,025.49	1,033,840.63	1,054,328.43
10.08355	0	2132.671	1	0	9	10	20758	0	186822	207580	(1,868,220.00)	No	44786.096	20487.80546	411008.4	34250.7	9318.2	0	9854460	793.3127	0	2478762.388	1532.445	0	14557.725	12,359,424.09	12,770,432.49	1,033,840.63	1,054,328.43
0	0	2369.635	0	0	10	10	0	0	207580	207580	(1,868,220.00)	No	49762.329	22764.22829	411008.4	34250.7	0.0	0	10949400	0	0	2754180.431	0	0	16175.25	13,719,755.68	14,130,764.08	1,033,840.63	1,056,604.86

Appendix C- Results 15% only

PV	wind	waste	scen	sce	scen	sum	Column2	Column3	Column4	Column5	Column6	diff	met	wastage	CO2waste	Cost Grid	Cost per month	PV Cap	wind Cap	waste capital	PV OM	wind OM	waste OM	PV rep	wind replacement	waste replacment	total (no grid)	total cost	gridCO2
0	35.54452	0	0	15	0	15	0	311370	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	0.0	61516.368	0	0	10474.4704	0	0	2852.93303	0	74,843.77	463,018.37	976,405.
10.08355	33.17489	0	1	14	0	15	20758	290612	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	9318.2	58098.792	0	793.3127	9892.55535	0	1532.445	2694.436751	0	82,329.76	470,504.36	976,405.
20.1671	30.80525	0	2	13	0	15	41516	269854	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	17789.3	52972.428	0	1514.506	9019.68282	0	2925.576	2456.692332	0	86,678.22	474,852.82	976,405.
30.25066	28.43562	0	3	12	0	15	62274	249096	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	26260.4	49554.852	0	2235.699	8437.7678	0	4318.707	2298.196052	0	93,105.66	481,280.26	976,405.
40.33421	26.06598	0	4	11	0	15	83032	228338	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	34731.6	46137.276	0	2956.893	7855.85278	0	5711.839	2139.699773	0	99,533.11	487,707.71	976,405.
50.41776	23.69635	0	5	10	0	15	103790	207580	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	43202.7	41010.912	0	3678.086	6982.98025	0	7104.97	1901.955353	0	103,881.57	492,056.17	976,405.
60.50131	21.32671	0	6	9	0	15	124548	186822	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	51673.8	37593.336	0	4399.279	6401.06523	0	8498.102	1743.459074	0	110,309.01	498,483.61	976,405.
70.58486	18.95708	0	7	8	0	15	145306	166064	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	60144.9	32466.972	0	5120.473	5528.1927	0	9891.233	1505.714655	0	114,657.47	502,832.07	976,405.
80.66842	16.58744	0	8	7	0	15	166064	145306	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	68616.0	29049.396	0	5841.666	4946.27768	0	11284.36	1347.218375	0	121,084.91	509,259.51	976,405.
90.75197	14.21781	0	9	6	0	15	186822	124548	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	77087.1	25631.82	0	6562.859	4364.36266	0	12677.5	1188.722096	0	127,512.36	515,686.96	976,405.
100.8355	11.84817	0	10	5	0	15	207580	103790	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	85558.2	20505.456	0	7284.053	3491.49013	0	14070.63	950.9776767	0	131,860.82	520,035.42	976,405.
110.9191	9.478539	0	11	4	0	15	228338	83032	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	94029.3	17087.88	0	8005.246	2909.5751	0	15463.76	792.4813973	0	138,288.26	526,462.86	976,405.
121.0026	7.108904	0	12	3	0	15	249096	62274	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	103347.5	13670.304	0	8798.559	2327.66008	0	16996.2	633.9851178	0	145,774.25	533,948.85	976,405.
131.0862	4.739269	0	13	2	0	15	269854	41516	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	111818.7	8543.94	0	9519.752	1454.78755	0	18389.34	396.2406986	0	150,122.71	538,297.31	976,405.
141.1697	2.369635	0	14	1	0	15	290612	20758	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	120289.8	5126.364	0	10240.95	872.872531	0	19782.47	237.7444192	0	156,550.16	544,724.76	976,405.
151.2533	0	0	15	0	0	15	311370	0	0	311370	15	(1,764,430.00)	No	0	0	388174.6	32347.88333	128760.9	0	0	10962.14	0	0	21175.6	0	0	160,898.61	549,073.21	976,405.
0	33.17489	236.9634703	0	14	1	15	0	290612	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	0.0	58098.792	974145.84	0	9892.55535	894372.1743	0	2694.436751	525263.1	2,464,466.90	2,852,641.50	976,405.
10.08355	30.80525	236.9634703	1	13	1	15	20758	269854	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	9318.2	52972.428	974145.84	793.3127	9019.68282	894372.1743	1532.445	2456.692332	525263.1	2,469,873.90	2,858,048.50	976,405.
20.1671	28.43562	236.9634703	2	12	1	15	41516	249096	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	17789.3	49554.852	974145.84	1514.506	8437.7678	894372.1743	2925.576	2298.196052	525263.1	2,476,301.34	2,864,475.94	976,405.
30.25066	26.06598	236.9634703	3	11	1	15	62274	228338	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	26260.4	46137.276	974145.84	2235.699	7855.85278	894372.1743	4318.707	2139.699773	525263.1	2,482,728.79	2,870,903.39	976,405.
40.33421	23.69635	236.9634703	4	10	1	15	83032	207580	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	34731.6	41010.912	974145.84	2956.893	6982.98025	894372.1743	5711.839	1901.955353	525263.1	2,487,077.24	2,875,251.84	976,405.
50.41776	21.32671	236.9634703	5	9	1	15	103790	186822	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	43202.7	37593.336	974145.84	3678.086	6401.06523	894372.1743	7104.97	1743.459074	525263.1	2,493,504.69	2,881,679.29	976,405.
60.50131	18.95708	236.9634703	6	8	1	15	124548	166064	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	51673.8	32466.972	974145.84	4399.279	5528.1927	894372.1743	8498.102	1505.714655	525263.1	2,497,853.15	2,886,027.75	976,405.
70.58486	16.58744	236.9634703	7	7	1	15	145306	145306	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	60144.9	29049.396	974145.84	5120.473	4946.27768	894372.1743	9891.233	1347.218375	525263.1	2,504,280.59	2,892,455.19	976,405.
80.66842	14.21781	236.9634703	8	6	1	15	166064	124548	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	68616.0	25631.82	974145.84	5841.666	4364.36266	894372.1743	11284.36	1188.722096	525263.1	2,510,708.04	2,898,882.64	976,405.
90.75197	11.84817	236.9634703	9	5	1	15	186822	103790	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	77087.1	20505.456	974145.84	6562.859	3491.49013	894372.1743	12677.5	950.9776767	525263.1	2,515,056.49	2,903,231.09	976,405.
100.8355	9.478539	236.9634703	10	4	1	15	207580	83032	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	85558.2	17087.88	974145.84	7284.053	2909.5751	894372.1743	14070.63	792.4813973	525263.1	2,521,483.94	2,909,658.54	976,405.
110.9191	7.108904	236.9634703	11	3	1	15	228338	62274	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	94029.3	13670.304	974145.84	8005.246	2327.66008	894372.1743	15463.76	633.9851178	525263.1	2,527,911.39	2,916,085.99	976,405.
121.0026	4.739269	236.9634703	12	2	1	15	249096	41516	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	103347.5	8543.94	974145.84	8798.559	1454.78755	894372.1743	16996.2	396.2406986	525263.1	2,533,318.39	2,921,492.99	976,405.
131.0862	2.369635	236.9634703	13	1	1	15	269854	20758	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	111818.7	5126.364	974145.84	9519.752	872.872531	894372.1743	18389.34	237.7444192	525263.1	2,539,745.83	2,927,920.43	976,405.
141.1697	0	236.9634703	14	0	1	15	290612	0	20758	311370	15	(1,764,430.00)	No	4976.2329	2276.422829	388174.6	32347.88333	120289.8	0	974145.84	10240.95	0	894372.1743	19782.47	0	525263.1	2,544,094.29	2,932,268.89	976,405.
0	30.80525	473.9269406	0	13	2	15	0	269854	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	0.0	52972.428	1948291.68	0	9019.68282	1788744.349	0	2456.692332	1050526.2	4,852,011.03	5,240,185.63	976,405.
10.08355	28.43562	473.9269406	1	12	2	15	20758	249096	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	9318.2	49554.852	1948291.68	793.3127	8437.7678	1788744.349	1532.445	2298.196052	1050526.2	4,859,497.02	5,247,671.62	976,405.
20.1671	26.06598	473.9269406	2	11	2	15	41516	228338	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	17789.3	46137.276	1948291.68	1514.506	7855.85278	1788744.349	2925.576	2139.699773	1050526.2	4,865,924.47	5,254,099.07	976,405.
30.25066	23.69635	473.9269406	3	10	2	15	62274	207580	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	26260.4	41010.912	1948291.68	2235.699	6982.98025	1788744.349	4318.707	1901.955353	1050526.2	4,870,272.92	5,258,447.52	976,405.
40.33421	21.32671	473.9269406	4	9	2	15	83032	186822	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	34731.6	37593.336	1948291.68	2956.893	6401.06523	1788744.349	5711.839	1743.459074	1050526.2	4,876,700.37	5,264,874.97	976,405.
50.41776	18.95708	473.9269406	5	8	2	15	103790	166064	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	43202.7	32466.972	1948291.68	3678.086	5528.1927	1788744.349	7104.97	1505.714655	1050526.2	4,881,048.83	5,269,223.43	976,405.

60.50131	16.58744	473.9269406	6	7	2	15	124548	145306	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	51673.8	29049.396	1948291.68	4399.279	4946.27768	1788744.349	8498.102	1347.218375	1050526.2	4,887,476.27	5,275,650.87	976,405.
70.58486	14.21781	473.9269406	7	6	2	15	145306	124548	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	60144.9	25631.82	1948291.68	5120.473	4364.36266	1788744.349	9891.233	1188.722096	1050526.2	4,893,903.72	5,282,078.32	976,405.
80.66842	11.84817	473.9269406	8	5	2	15	166064	103790	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	68616.0	20505.456	1948291.68	5841.666	3491.49013	1788744.349	11284.36	950.9776767	1050526.2	4,898,252.17	5,286,426.77	976,405.
90.75197	9.478539	473.9269406	9	4	2	15	186822	83032	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	77087.1	17087.88	1948291.68	6562.859	2909.5751	1788744.349	12677.5	792.4813973	1050526.2	4,904,679.62	5,292,854.22	976,405.
100.8355	7.108904	473.9269406	10	3	2	15	207580	62274	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	85558.2	13670.304	1948291.68	7284.053	2327.66008	1788744.349	14070.63	633.9851178	1050526.2	4,911,107.07	5,299,281.67	976,405.
110.9191	4.739269	473.9269406	11	2	2	15	228338	41516	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	94029.3	8543.94	1948291.68	8005.246	1454.78755	1788744.349	15463.76	396.2406986	1050526.2	4,915,455.52	5,303,630.12	976,405.
121.0026	2.369635	473.9269406	12	1	2	15	249096	20758	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	103347.5	5126.364	1948291.68	8798.559	872.872531	1788744.349	16996.2	237.7444192	1050526.2	4,922,941.51	5,311,116.11	976,405.
131.0862	0	473.9269406	13	0	2	15	269854	0	41516	311370	15	(1,764,430.00)	No	9952.4658	4552.845657	388174.6	32347.88333	111818.7	0	1948291.68	9519.752	0	1788744.349	18389.34	0	1050526.2	4,927,289.97	5,315,464.57	976,405.
0	28.43562	710.890411	0	12	3	15	0	249096	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	0.0	49554.852	2922437.52	0	8437.7678	2683116.523	0	2298.196052	1575789.3	7,241,634.16	7,629,808.76	976,405.
10.08355	26.06598	710.890411	1	11	3	15	20758	228338	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	9318.2	46137.276	2922437.52	793.3127	7855.85278	2683116.523	1532.445	2139.699773	1575789.3	7,249,120.15	7,637,294.75	976,405.
20.1671	23.69635	710.890411	2	10	3	15	41516	207580	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	17789.3	41010.912	2922437.52	1514.506	6982.98025	2683116.523	2925.576	1901.955353	1575789.3	7,253,468.60	7,641,643.20	976,405.
30.25066	21.32671	710.890411	3	9	3	15	62274	186822	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	26260.4	37593.336	2922437.52	2235.699	6401.06523	2683116.523	4318.707	1743.459074	1575789.3	7,259,896.05	7,648,070.65	976,405.
40.33421	18.95708	710.890411	4	8	3	15	83032	166064	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	34731.6	32466.972	2922437.52	2956.893	5528.1927	2683116.523	5711.839	1505.714655	1575789.3	7,264,244.50	7,652,419.10	976,405.
50.41776	16.58744	710.890411	5	7	3	15	103790	145306	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	43202.7	29049.396	2922437.52	3678.086	4946.27768	2683116.523	7104.97	1347.218375	1575789.3	7,270,671.95	7,658,846.55	976,405.
60.50131	14.21781	710.890411	6	6	3	15	124548	124548	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	51673.8	25631.82	2922437.52	4399.279	4364.36266	2683116.523	8498.102	1188.722096	1575789.3	7,277,099.40	7,665,274.00	976,405.
70.58486	11.84817	710.890411	7	5	3	15	145306	103790	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	60144.9	20505.456	2922437.52	5120.473	3491.49013	2683116.523	9891.233	950.9776767	1575789.3	7,281,447.85	7,669,622.45	976,405.
80.66842	9.478539	710.890411	8	4	3	15	166064	83032	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	68616.0	17087.88	2922437.52	5841.666	2909.5751	2683116.523	11284.36	792.4813973	1575789.3	7,287,875.30	7,676,049.90	976,405.
90.75197	7.108904	710.890411	9	3	3	15	186822	62274	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	77087.1	13670.304	2922437.52	6562.859	2327.66008	2683116.523	12677.5	633.9851178	1575789.3	7,294,302.75	7,682,477.35	976,405.
100.8355	4.739269	710.890411	10	2	3	15	207580	41516	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	85558.2	8543.94	2922437.52	7284.053	1454.78755	2683116.523	14070.63	396.2406986	1575789.3	7,298,651.20	7,686,825.80	976,405.
110.9191	2.369635	710.890411	11	1	3	15	228338	20758	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	94029.3	5126.364	2922437.52	8005.246	872.872531	2683116.523	15463.76	237.7444192	1575789.3	7,305,078.65	7,693,253.25	976,405.
121.0026	0	710.890411	12	0	3	15	249096	0	62274	311370	15	(1,764,430.00)	No	14928.699	6829.268486	388174.6	32347.88333	103347.5	0	2922437.52	8798.559	0	2683116.523	16996.2	0	1575789.3	7,310,485.65	7,698,660.25	976,405.
0	26.06598	947.8538813	0	11	4	15	0	228338	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	0.0	46137.276	3896583.36	0	7855.85278	3577488.697	0	2139.699773	2101052.4	9,631,257.29	10,019,431.89	976,405.
10.08355	23.69635	947.8538813	1	10	4	15	20758	207580	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	9318.2	41010.912	3896583.36	793.3127	6982.98025	3577488.697	1532.445	1901.955353	2101052.4	9,636,664.28	10,024,838.88	976,405.
20.1671	21.32671	947.8538813	2	9	4	15	41516	186822	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	17789.3	37593.336	3896583.36	1514.506	6401.06523	3577488.697	2925.576	1743.459074	2101052.4	9,643,091.73	10,031,266.33	976,405.
30.25066	18.95708	947.8538813	3	8	4	15	62274	166064	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	26260.4	32466.972	3896583.36	2235.699	5528.1927	3577488.697	4318.707	1505.714655	2101052.4	9,647,440.18	10,035,614.78	976,405.
40.33421	16.58744	947.8538813	4	7	4	15	83032	145306	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	34731.6	29049.396	3896583.36	2956.893	4946.27768	3577488.697	5711.839	1347.218375	2101052.4	9,653,867.63	10,042,042.23	976,405.
50.41776	14.21781	947.8538813	5	6	4	15	103790	124548	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	43202.7	25631.82	3896583.36	3678.086	4364.36266	3577488.697	7104.97	1188.722096	2101052.4	9,660,295.08	10,048,469.68	976,405.
60.50131	11.84817	947.8538813	6	5	4	15	124548	103790	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	51673.8	20505.456	3896583.36	4399.279	3491.49013	3577488.697	8498.102	950.9776767	2101052.4	9,664,643.53	10,052,818.13	976,405.
70.58486	9.478539	947.8538813	7	4	4	15	145306	83032	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	60144.9	17087.88	3896583.36	5120.473	2909.5751	3577488.697	9891.233	792.4813973	2101052.4	9,671,070.98	10,059,245.58	976,405.
80.66842	7.108904	947.8538813	8	3	4	15	166064	62274	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	68616.0	13670.304	3896583.36	5841.666	2327.66008	3577488.697	11284.36	633.9851178	2101052.4	9,677,498.43	10,065,673.03	976,405.
90.75197	4.739269	947.8538813	9	2	4	15	186822	41516	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	77087.1	8543.94	3896583.36	6562.859	1454.78755	3577488.697	12677.5	396.2406986	2101052.4	9,681,846.88	10,070,021.48	976,405.
100.8355	2.369635	947.8538813	10	1	4	15	207580	20758	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	85558.2	5126.364	3896583.36	7284.053	872.872531	3577488.697	14070.63	237.7444192	2101052.4	9,688,274.33	10,076,448.93	976,405.
110.9191	0	947.8538813	11	0	4	15	228338	0	83032	311370	15	(1,764,430.00)	No	19904.932	9105.691315	388174.6	32347.88333	94029.3	0	3896583.36	8005.246	0	3577488.697	15463.76	0	2101052.4	9,692,622.78	10,080,797.38	976,405.
0	23.69635	1184.817352	0	10	5	15	0	207580	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	0.0	41010.912	4870729.2	0	6982.98025	4471860.871	0	1901.955353	2626315.5	12,018,801.42	12,406,976.02	976,405.
10.08355	21.32671	1184.817352	1	9	5	15	20758	186822	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	9318.2	37593.336	4870729.2	793.3127	6401.06523	4471860.871	1532.445	1743.459074	2626315.5	12,026,287.41	12,414,462.01	976,405.
20.1671	18.95708	1184.817352	2	8	5	15	41516	166064	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	17789.3	32466.972	4870729.2	1514.506	5528.1927	4471860.871	2925.576	1505.714655	2626315.5	12,030,635.86	12,418,810.46	976,405.
30.25066	16.58744	1184.817352	3	7	5	15	62274	145306	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	26260.4	29049.396	4870729.2	2235.699	4946.27768	4471860.871	4318.707	1347.218375	2626315.5	12,037,063.31	12,425,237.91	976,405.
40.33421	14.21781	1184.817352	4	6	5	15	83032	124548	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	34731.6	25631.82	4870729.2	2956.893	4364.36266	4471860.871	5711.839	1188.722096	2626315.5	12,043,490.76	12,431,665.36	976,405.
50.41776	11.84817	1184.817352	5	5	5	15	103790	103790	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	43202.7	20505.456	4870729.2	3678.086	3491.49013	4471860.871	7104.97	950.9776767	2626315.5	12,047,839.21	12,436,013.81	976,405.

60.50131	9.478539	1184.817352	6	4	5	15	124548	83032	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	51673.8	17087.88	4870729.2	4399.279	2909.5751	4471860.871	8498.102	792.4813973	2626315.5	12,054,266.66	12,442,441.26	976,405.
70.58486	7.108904	1184.817352	7	3	5	15	145306	62274	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	60144.9	13670.304	4870729.2	5120.473	2327.66008	4471860.871	9891.233	633.9851178	2626315.5	12,060,694.11	12,448,868.71	976,405.
80.66842	4.739269	1184.817352	8	2	5	15	166064	41516	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	68616.0	8543.94	4870729.2	5841.666	1454.78755	4471860.871	11284.36	396.2406986	2626315.5	12,065,042.56	12,453,217.16	976,405.
90.75197	2.369635	1184.817352	9	1	5	15	186822	20758	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	77087.1	5126.364	4870729.2	6562.859	872.872531	4471860.871	12677.5	237.7444192	2626315.5	12,071,470.01	12,459,644.61	976,405.
100.8355	0	1184.817352	10	0	5	15	207580	0	103790	311370	15	(1,764,430.00)	No	24881.164	11382.11414	388174.6	32347.88333	85558.2	0	4870729.2	7284.053	0	4471860.871	14070.63	0	2626315.5	12,075,818.46	12,463,993.06	976,405.
0	21.32671	1421.780822	0	9	6	15	0	186822	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	0.0	37593.336	5844875.04	0	6401.06523	5366233.046	0	1743.459074	3151578.6	14,408,424.55	14,796,599.15	976,405.
10.08355	18.95708	1421.780822	1	8	6	15	20758	166064	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	9318.2	32466.972	5844875.04	793.3127	5528.1927	5366233.046	1532.445	1505.714655	3151578.6	14,413,831.54	14,802,006.14	976,405.
20.1671	16.58744	1421.780822	2	7	6	15	41516	145306	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	17789.3	29049.396	5844875.04	1514.506	4946.27768	5366233.046	2925.576	1347.218375	3151578.6	14,420,258.99	14,808,433.59	976,405.
30.25066	14.21781	1421.780822	3	6	6	15	62274	124548	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	26260.4	25631.82	5844875.04	2235.699	4364.36266	5366233.046	4318.707	1188.722096	3151578.6	14,426,686.44	14,814,861.04	976,405.
40.33421	11.84817	1421.780822	4	5	6	15	83032	103790	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	34731.6	20505.456	5844875.04	2956.893	3491.49013	5366233.046	5711.839	950.9776767	3151578.6	14,431,034.89	14,819,209.49	976,405.
50.41776	9.478539	1421.780822	5	4	6	15	103790	83032	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	43202.7	17087.88	5844875.04	3678.086	2909.5751	5366233.046	7104.97	792.4813973	3151578.6	14,437,462.34	14,825,636.94	976,405.
60.50131	7.108904	1421.780822	6	3	6	15	124548	62274	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	51673.8	13670.304	5844875.04	4399.279	2327.66008	5366233.046	8498.102	633.9851178	3151578.6	14,443,889.79	14,832,064.39	976,405.
70.58486	4.739269	1421.780822	7	2	6	15	145306	41516	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	60144.9	8543.94	5844875.04	5120.473	1454.78755	5366233.046	9891.233	396.2406986	3151578.6	14,448,238.24	14,836,412.84	976,405.
80.66842	2.369635	1421.780822	8	1	6	15	166064	20758	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	68616.0	5126.364	5844875.04	5841.666	872.872531	5366233.046	11284.36	237.7444192	3151578.6	14,454,665.69	14,842,840.29	976,405.
90.75197	0	1421.780822	9	0	6	15	186822	0	124548	311370	15	(1,764,430.00)	No	29857.397	13658.53697	388174.6	32347.88333	77087.1	0	5844875.04	6562.859	0	5366233.046	12677.5	0	3151578.6	14,459,014.14	14,847,188.74	976,405.
0	18.95708	1658.744292	0	8	7	15	0	166064	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	0.0	32466.972	6819020.88	0	5528.1927	6260605.22	0	1505.714655	3676841.7	16,795,968.68	17,184,143.28	976,405.
10.08355	16.58744	1658.744292	1	7	7	15	20758	145306	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	9318.2	29049.396	6819020.88	793.3127	4946.27768	6260605.22	1532.445	1347.218375	3676841.7	16,803,454.67	17,191,629.27	976,405.
20.1671	14.21781	1658.744292	2	6	7	15	41516	124548	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	17789.3	25631.82	6819020.88	1514.506	4364.36266	6260605.22	2925.576	1188.722096	3676841.7	16,809,882.12	17,198,056.72	976,405.
30.25066	11.84817	1658.744292	3	5	7	15	62274	103790	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	26260.4	20505.456	6819020.88	2235.699	3491.49013	6260605.22	4318.707	950.9776767	3676841.7	16,814,230.57	17,202,405.17	976,405.
40.33421	9.478539	1658.744292	4	4	7	15	83032	83032	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	34731.6	17087.88	6819020.88	2956.893	2909.5751	6260605.22	5711.839	792.4813973	3676841.7	16,820,658.02	17,208,832.62	976,405.
50.41776	7.108904	1658.744292	5	3	7	15	103790	62274	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	43202.7	13670.304	6819020.88	3678.086	2327.66008	6260605.22	7104.97	633.9851178	3676841.7	16,827,085.47	17,215,260.07	976,405.
60.50131	4.739269	1658.744292	6	2	7	15	124548	41516	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	51673.8	8543.94	6819020.88	4399.279	1454.78755	6260605.22	8498.102	396.2406986	3676841.7	16,831,433.92	17,219,608.52	976,405.
70.58486	2.369635	1658.744292	7	1	7	15	145306	20758	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	60144.9	5126.364	6819020.88	5120.473	872.872531	6260605.22	9891.233	237.7444192	3676841.7	16,837,861.37	17,226,035.97	976,405.
80.66842	0	1658.744292	8	0	7	15	166064	0	145306	311370	15	(1,764,430.00)	No	34833.63	15934.9598	388174.6	32347.88333	68616.0	0	6819020.88	5841.666	0	6260605.22	11284.36	0	3676841.7	16,842,209.82	17,230,384.42	976,405.
0	16.58744	1895.707763	0	7	8	15	0	145306	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	0.0	29049.396	7793166.72	0	4946.27768	7154977.394	0	1347.218375	4202104.8	19,185,591.81	19,573,766.41	976,405.
10.08355	14.21781	1895.707763	1	6	8	15	20758	124548	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	9318.2	25631.82	7793166.72	793.3127	4364.36266	7154977.394	1532.445	1188.722096	4202104.8	19,193,077.80	19,581,252.40	976,405.
20.1671	11.84817	1895.707763	2	5	8	15	41516	103790	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	17789.3	20505.456	7793166.72	1514.506	3491.49013	7154977.394	2925.576	950.9776767	4202104.8	19,197,426.25	19,585,600.85	976,405.
30.25066	9.478539	1895.707763	3	4	8	15	62274	83032	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	26260.4	17087.88	7793166.72	2235.699	2909.5751	7154977.394	4318.707	792.4813973	4202104.8	19,203,853.70	19,592,028.30	976,405.
40.33421	7.108904	1895.707763	4	3	8	15	83032	62274	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	34731.6	13670.304	7793166.72	2956.893	2327.66008	7154977.394	5711.839	633.9851178	4202104.8	19,210,281.15	19,598,455.75	976,405.
50.41776	4.739269	1895.707763	5	2	8	15	103790	41516	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	43202.7	8543.94	7793166.72	3678.086	1454.78755	7154977.394	7104.97	396.2406986	4202104.8	19,214,629.60	19,602,804.20	976,405.
60.50131	2.369635	1895.707763	6	1	8	15	124548	20758	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	51673.8	5126.364	7793166.72	4399.279	872.872531	7154977.394	8498.102	237.7444192	4202104.8	19,221,057.05	19,609,231.65	976,405.
70.58486	0	1895.707763	7	0	8	15	145306	0	166064	311370	15	(1,764,430.00)	No	39809.863	18211.38263	388174.6	32347.88333	60144.9	0	7793166.72	5120.473	0	7154977.394	9891.233	0	4202104.8	19,225,405.50	19,613,580.10	976,405.
0	14.21781	2132.671233	0	6	9	15	0	124548	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	0.0	25631.82	8767312.56	0	4364.36266	8049349.569	0	1188.722096	4727367.9	21,575,214.93	21,963,389.53	976,405.
10.08355	11.84817	2132.671233	1	5	9	15	20758	103790	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	9318.2	20505.456	8767312.56	793.3127	3491.49013	8049349.569	1532.445	950.9776767	4727367.9	21,580,621.93	21,968,796.53	976,405.
20.1671	9.478539	2132.671233	2	4	9	15	41516	83032	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	17789.3	17087.88	8767312.56	1514.506	2909.5751	8049349.569	2925.576	792.4813973	4727367.9	21,587,049.38	21,975,223.98	976,405.
30.25066	7.108904	2132.671233	3	3	9	15	62274	62274	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	26260.4	13670.304	8767312.56	2235.699	2327.66008	8049349.569	4318.707	633.9851178	4727367.9	21,593,476.83	21,981,651.43	976,405.
40.33421	4.739269	2132.671233	4	2	9	15	83032	41516	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	34731.6	8543.94	8767312.56	2956.893	1454.78755	8049349.569	5711.839	396.2406986	4727367.9	21,597,825.28	21,985,999.88	976,405.
50.41776	2.369635	2132.671233	5	1	9	15	103790	20758	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	43202.7	5126.364	8767312.56	3678.086	872.872531	8049349.569	7104.97	237.7444192	4727367.9	21,604,252.73	21,992,427.33	976,405.
60.50131	0	2132.671233	6	0	9	15	124548	0	186822	311370	15	(1,764,430.00)	No	44786.096	20487.80546	388174.6	32347.88333	51673.8	0	8767312.56	4399.279	0	8049349.569	8498.102	0	4727367.9	21,608,601.18	21,996,775.78	976,405.

0	11.84817	2369.634703	0	5	10	15	0	103790	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	0.0	20505.456	9741458.4	0	3491.49013	8943721.743	0	950.9776767	5252631	23,962,759.07	24,350,933.67	976,405.
10.08355	9.478539	2369.634703	1	4	10	15	20758	83032	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	9318.2	17087.88	9741458.4	793.3127	2909.5751	8943721.743	1532.445	792.4813973	5252631	23,970,245.06	24,358,419.66	976,405.
20.1671	7.108904	2369.634703	2	3	10	15	41516	62274	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	17789.3	13670.304	9741458.4	1514.506	2327.66008	8943721.743	2925.576	633.9851178	5252631	23,976,672.51	24,364,847.11	976,405.
30.25066	4.739269	2369.634703	3	2	10	15	62274	41516	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	26260.4	8543.94	9741458.4	2235.699	1454.78755	8943721.743	4318.707	396.2406986	5252631	23,981,020.96	24,369,195.56	976,405.
40.33421	2.369635	2369.634703	4	1	10	15	83032	20758	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	34731.6	5126.364	9741458.4	2956.893	872.872531	8943721.743	5711.839	237.7444192	5252631	23,987,448.41	24,375,623.01	976,405.
50.41776	0	2369.634703	5	0	10	15	103790	0	207580	311370	15	(1,764,430.00)	No	49762.329	22764.22829	388174.6	32347.88333	43202.7	0	9741458.4	3678.086	0	8943721.743	7104.97	0	5252631	23,991,796.86	24,379,971.46	976,405.
0	9.478539	2606.598174	0	4	11	15	0	83032	228338	311370	15	(1,764,430.00)	No	54738.562	25040.65112	388174.6	32347.88333	0.0	17087.88	10715604.24	0	2909.5751	9838093.917	0	792.4813973	5777894.1	26,352,382.19	26,740,556.79	976,405.
10.08355	7.108904	2606.598174	1	3	11	15	20758	62274	228338	311370	15	(1,764,430.00)	No	54738.562	25040.65112	388174.6	32347.88333	9318.2	13670.304	10715604.24	793.3127	2327.66008	9838093.917	1532.445	633.9851178	5777894.1	26,359,868.18	26,748,042.78	976,405.
20.1671	4.739269	2606.598174	2	2	11	15	41516	41516	228338	311370	15	(1,764,430.00)	No	54738.562	25040.65112	388174.6	32347.88333	17789.3	8543.94	10715604.24	1514.506	1454.78755	9838093.917	2925.576	396.2406986	5777894.1	26,364,216.64	26,752,391.24	976,405.
30.25066	2.369635	2606.598174	3	1	11	15	62274	20758	228338	311370	15	(1,764,430.00)	No	54738.562	25040.65112	388174.6	32347.88333	26260.4	5126.364	10715604.24	2235.699	872.872531	9838093.917	4318.707	237.7444192	5777894.1	26,370,644.09	26,758,818.69	976,405.
40.33421	0	2606.598174	4	0	11	15	83032	0	228338	311370	15	(1,764,430.00)	No	54738.562	25040.65112	388174.6	32347.88333	34731.6	0	10715604.24	2956.893	0	9838093.917	5711.839	0	5777894.1	26,374,992.54	26,763,167.14	976,405.
0	7.108904	2843.561644	0	3	12	15	0	62274	249096	311370	15	(1,764,430.00)	No	59714.795	27317.07394	388174.6	32347.88333	0.0	13670.304	11689750.08	0	2327.66008	10732466.09	0	633.9851178	6303157.2	28,742,005.32	29,130,179.92	976,405.
10.08355	4.739269	2843.561644	1	2	12	15	20758	41516	249096	311370	15	(1,764,430.00)	No	59714.795	27317.07394	388174.6	32347.88333	9318.2	8543.94	11689750.08	793.3127	1454.78755	10732466.09	1532.445	396.2406986	6303157.2	28,747,412.32	29,135,586.92	976,405.
20.1671	2.369635	2843.561644	2	1	12	15	41516	20758	249096	311370	15	(1,764,430.00)	No	59714.795	27317.07394	388174.6	32347.88333	17789.3	5126.364	11689750.08	1514.506	872.872531	10732466.09	2925.576	237.7444192	6303157.2	28,753,839.77	29,142,014.37	976,405.
30.25066	0	2843.561644	3	0	12	15	62274	0	249096	311370	15	(1,764,430.00)	No	59714.795	27317.07394	388174.6	32347.88333	26260.4	0	11689750.08	2235.699	0	10732466.09	4318.707	0	6303157.2	28,758,188.22	29,146,362.82	976,405.
0	4.739269	3080.525114	0	2	13	15	0	41516	269854	311370	15	(1,764,430.00)	No	64691.027	29593.49677	388174.6	32347.88333	0.0	8543.94	12663895.92	0	1454.78755	11626838.27	0	396.2406986	6828420.3	31,129,549.45	31,517,724.05	976,405.
10.08355	2.369635	3080.525114	1	1	13	15	20758	20758	269854	311370	15	(1,764,430.00)	No	64691.027	29593.49677	388174.6	32347.88333	9318.2	5126.364	12663895.92	793.3127	872.872531	11626838.27	1532.445	237.7444192	6828420.3	31,137,035.45	31,525,210.05	976,405.
20.1671	0	3080.525114	2	0	13	15	41516	0	269854	311370	15	(1,764,430.00)	No	64691.027	29593.49677	388174.6	32347.88333	17789.3	0	12663895.92	1514.506	0	11626838.27	2925.576	0	6828420.3	31,141,383.90	31,529,558.50	976,405.
0	2.369635	3317.488584	0	1	14	15	0	20758	290612	311370	15	(1,764,430.00)	No	69667.26	31869.9196	388174.6	32347.88333	0.0	5126.364	13638041.76	0	872.872531	12521210.44	0	237.7444192	7353683.4	33,519,172.58	33,907,347.18	976,405.
10.08355	0	3317.488584	1	0	14	15	20758	0	290612	311370	15	(1,764,430.00)	No	69667.26	31869.9196	388174.6	32347.88333	9318.2	0	13638041.76	793.3127	0	12521210.44	1532.445	0	7353683.4	33,524,579.58	33,912,754.18	976,405.
0	0	3554.452055	0	0	15	15	0	0	311370	311370	15	(1,764,430.00)	No	74643.493	34146.34243	388174.6	32347.88333	0.0	0	14612187.6	0	0	13415582.61	0	0	7878946.5	35,906,716.71	36,294,891.31	976,405.