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The effectiveness of small scale Photovoltaic (PV) systems design and cost analysis simulation on Saudi Arabian Economy

Faris Abdullah Almansour

North Carolina A&T State University

A thesis submitted to the graduate faculty

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Department: Computer Science Technology

Major: Information Technology

Major Professor: Dr. Ibraheem Kateeb

Greensboro, North Carolina

2013

School of Graduate Studies
North Carolina Agricultural and Technical State University
This is to certify that the Master's Thesis of

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Faris Abdullah Almansour

2013

Biographical Sketch

Faris Almansour was born 28 June 1976 in Najran, SA. He received a Bachelor of Science in Information Technology from Arab Open University in Dammam, SA in 2009. Since receiving his degree in Information Technology he has held various job positions in power generation and Information Technology.

Dedication

For my beloved family, my loved wife and our kids

Abdullah, Mohammed and Lamar

Acknowledgements

I would like to begin by thanking my advisor, Dr. Ibraheem Kateeb, for his patience and guidance in helping me through this academic challenge. I would not have been able to complete this project without his wealth of knowledge and years of experience. Also I want to thank the faculty from School of Technology for their help and support. They have taught and instructed me in advancing my education for the last two and a half years. I would especially like to thank Dr. Larry Burton, Dr. Rajeev Agrawal, Dr. Evelyn Sowells and Dr. Li-Shiang Tsay for helping and supporting me over the years. Most importantly, I wish to thank my family for all the support and sacrifices they have made while I have been in pursuit of this degree, which I hope will one day better all of our lives. I will not forget to thank Ms. Kate Newman for editing my thesis. Finally I would like to sincerely thank my parents for giving me their love and support at the first place and brining up me spiritually throughout my life.

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Abstract

The advantages of Renewable Energy Sources (RES) are much more than the disadvantages, RES such as solar, wind energy, biomass, and geothermal, which can be used for generating distributed power but cannot directly replace the existing electric energy grid technologies. The latter are far too well established to abandon, while the new RES technologies are not sufficiently developed to meet the total energy demand. Therefore, it is sensible to gradually infuse RES into existing grids and transform the system over time

Saudi Arabia (SA) is a semi-developed nation with a population of over twenty nine million people. It is the largest country in western Asia with an area of 2.225MKm^2. SA's largest export is oil, owning 1/5 of the world's supply, and producing twelve million barrels a day. However, SA is far behind in developing a smart grid and RES. A lot of this is to do with lack of participation by both the government and the private business sector. Currently SA spends over $13B a year on generating electricity from oil.

SA is the largest consumer of petroleum in the Middle East, due to the high demand for transportation and electricity generation. According to the Saudi electrical company, the total amount of generated power in 2011 was 190.280GW. In addition, SA's electricity consumption is currently growing 8% a year. SA aims to generate 55GW of renewable energy by 2020, in order to free up fossil fuels for export. 41GW of the 55GW will be generated from solar energy. Smart grid technologies are also under consideration in SA; this will allow an efficient and reliable way to control the energy in the future. In addition, the potential for wind and geothermal energy is very high. In this thesis, there is a full exploration of RES components which are critical to manage carbon emission and the limitations of the current grid to the new RES technologies, which face barriers to full- scale deployment.

A study in Dhahran, SA has been simulated on a installing a Dual-Tariff PV system using HOMER. The result of the simulation has been discussed, analyzed, and plotted. We also give evidence in the thesis how useful the small PV systems can be as oppose to the larger scale system that must deal with location issues.

CHAPTER 1

Introduction

1.1 Introduction

Modern power distribution systems made abundant energy reliable, available, and relatively independent from the plant location. More than two centuries of past industrialization exploited nonrenewable energy resources, however, often with undesirable side effects such as pollution and other damage to the natural environment. In the second half of the 20th century, extraction of energy from nuclear processes grew in popularity, relieving some demands on limited fossil fuel reserves, but at the same time, raising safety and political problems. Meeting the global demand for energy is now the key challenge to sustaining industrialization. Industrialization and economic development have historically been associated with one's ability to harness natural energy resources to improve the human condition.

Issues such as a lack of reliability and efficiency in power processing systems allow tremendous room for the exploitation of the enormous potential of renewable energy sources. It does so by transforming the maximum available power into an electrical whole, which is fed into a grid or converted into high density energy for being stored and used in another place at another time. A primary energy source not available is one of the main issues discussed in Smart Grid. In 2008, emissions of carbon dioxide from fuel burning in the United States were down 2.8%, the biggest annual drop since the 1980s (Kateeb, Burton, El-Bathy, and Almansour, 2012). The Smart Grid enables grid operators to see further into the power systems and allows them the flexibility to better manage the intermittency of Renewable Energy Sources. This in turn presents a significant potential, enabling wind and solar to be deployed rapidly – and in larger percentages to have a green Smart Grid.

1.2 Green Energy

Going green through the use of RES and making the planet sustainable improves the air quality and the environment. The US government has required that by the year 2030 that 20% of the electrical energy generated in the U S will be from RES. There are many different types of RES such as hydroelectric, biomass, wind, solar, geothermal, wave, and geothermal. The key to the usage of renewable resources is that they are replenished by nature. In addition, they also have the advantage of having low or no emissions of carbons which make them more environmentally friendly than the old energy sources such as fossil fuels.

The concept of the Smart Grid was first put forward in 2003. In accordance with IBM, the "Smart Grid" has three characteristics: first, a higher degree of digitalization, containing a variety of intelligent sensors, such as electrical equipment, control systems, application systems, etc., and connecting more devices; second, it is based on a unified information platform, which can finish the integration of data and application automatically; third, it is based on business intelligence analysis system, and has the capabilities of assisting decision support for data analysis, that is, to optimize the operation and management according to the correlation analysis of existing power grid data (Kateeb, Burton, El-Bathy, and Almansour, 2012). The discussion of RES will bring many issues to the table such as: efficiency, reliability, sustainability, cost of the energy conversion, capability to forecast energy production, safe connection to the electric grid and/or capability to manage The Micro grid. All of these issues need to be resolved to have a better performing grid, efficient energy storage, and the ability to transport energy with low environmental impact. In addition there is necessity for development of advanced control and monitoring systems, networking of the sources/consumers, and availability of good tools for the study and research of RES.

1.3 Electricity Development

The discovery of electricity in the middle of the 19th century supported the industrial revolution at that time. Electrical power had been used for lighting and driving mechanical forces. Since then, people burned fossil fuels in an enormous way to generate electricity to meet their demand of power. The demand for electricity will be doubled many times especially for the upcoming centuries due to the economic development and industrialization, which has raised the fuel price and consumption. This increase has caused a lot of damage to the environment, such as water pollution and global warming.

During the second half of the 20th century people started thinking about the environment and global warming and how to avoid using fossil fuels. They found that heat and emission gases from burning fossil fuels were one of the most detrimental causes of global warming. So, there needed to be an alternative way to reduce the fossil fuel burning. Therefore other aspects were approached to generate energy from green resources such as wind, nuclear plants, solar systems and other RES. The most exploited RES are hydroelectric, photovoltaic, (PV) and wind (Kateeb, Burton, El-Bathy, and Almansour, 2012). In 2007, the world's renewable energy production share was calculated as 19%. Moreover, 16% is due to hydroelectric energy production and wind and PV energy production is still very modest.

PV and wind energy are the most promising forms of renewable energies but have very different requirements to be produced and incorporated in the new system (Kateeb, Burton, El-Bathy, and Almansour, 2012). In 2012, wind energy became well established; being more than 3% of the world's energy production, and PV energy is experiencing an impressive growth. Other emerging renewable technologies include wave and tidal energy conversion, biomass energy conversion with focus on combined heat and power (CHP), and small-scale hydroelectric plants (less than 10 MW per site).The global wind energy production forecast until the end of the 2012 is expected to be 273 GW (WWEA, 2012).

In contrast, the PV industry is growing at more than 30% per year, and the cost of PV energy will reach the break-even point soon in many countries. The electrical infrastructure of today's grid was designed over a half a century ago. The load demand is increasing continuously, whereas the electrical grid is becoming dated. In 2012, according to the U.S. Energy Information Administration there is a 1.3% and 3.5% increase in energy consumption (Annual Energy Outlook, 2012).

Many countries around the world are making progress with smart grids and renewable energy resources. The United States, China, and Germany are three of the most advanced countries. They all have smart grids and also are very advanced with wind and solar (PV) energy. They are also making advancements with geothermal, biomass, hydro-electric, and fuel cells. SA is a country in the Middle East that has endless potential for using renewable energy resources. SA has an extremely hot climate, which gives it tremendous potential for solar and geothermal energy. In addition, SA is surrounded by coastal area so it has tremendous potential for wind. Currently King Abdullah has announced the creation of King Abdullah City of Atomic and Renewable Energy (KACARE). This city contributes the funding for the development of RES in SA.

Unfortunately there is very little installed capacity of clean green renewable energy in SA. However, there are many studies of solar, wind, and geothermal energy. The development of RES in SA is very important on an economical level. If the nation can start using RES, then it can save its oil for export and profit. SA is the leading exporter of oil in the world. In addition there is little work being done with hydro-electric, biomass, or fuel cells. There is a very useful program SA and the western countries have access to for designing renewable resource systems. The software is called HOMER and was originally created by The National Renewable Energy Laboratory in Boulder, Colorado. For years industrialized nations have developed the use of smart grids and RES. Nations such as the United States, China, and Germany who are used to importing fossil fuels are currently the world leaders in the development of smart grids and RES. However, SA has begun using some RES but on a much lesser scale. Also, SA is still on the old electrical grid. The HOMER software has been used to show a dual-tariff simulation in Dhahran, which depicts the strength and usefulness of a PV system for this part of SA.

CHAPTER 2

The Smart Grid (United States)

2.1 Introduction

The concept of the Smart Grid was first put forward in 2003. The Concept is a modern and efficient method in which a consumer's energy consumption can be monitored, controlled, and predicated. In accordance with the IBM, the Smart Grid has three characteristics: first, a higher degree of digitalization, containing a variety of intelligent sensors, such as electrical equipment, control systems, application systems, etc., and connecting more devices. Second, it is based on a unified information platform, which can finish the integration of data and application automatically. Third, it is based on a business intelligence analysis system, and it has the capabilities of assisting decision support for data analysis, that is, to optimize the operation and management according to the correlation analysis of existing power grid data (Kateeb, Burton, Al-baathy, and Almansour, 2012).

Smart grid is utilized as a resource to help the consumer gain energy independence, stop the release of greenhouse gases through green RES's and conservation of energy, and the consumers also gain the ability to better control their utility bill due to the green energy that comes along with the smart grid. The smart grid has computerized device called a smart meter, which is used in net metering to quantify the energy a consumer both contributes and utilizes to the smart grid. Unfortunately, because the smart grid is computerized and connected to network, security becomes an issue. However, the smart grid is still a huge development in humanity, so the United States Energy Department has created Grants to deploy and develop the smart grid in accordance with the 2030 goals to be met.

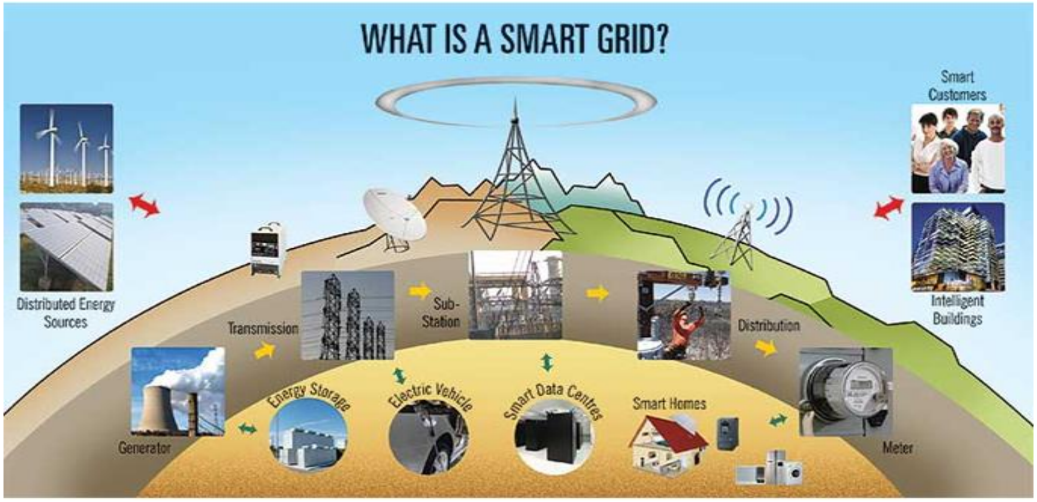

Figure1. Smart grid.

2.2 Power Processing Systems

The smart grid has turned all available power into an electrical whole, by converting it into high density energy to be stored and used in another place at another time; and as a result, made power processing systems more efficient. For example, the smart grid speeds up the process of disaster recovery because it has many resources. Therefore, when one energy source is experiencing power failure, there are other sources of energy to compensate. Also, the infrastructure of the new grid will make it easier to detect fault locations. The smart sensors will alert the network operator to the problem, which will enable him to quickly and efficiently troubleshoot and repair the network. The Smart Grid enables grid operators to see farther into the future and allows them the flexibility to better manage the intermittency of renewable energy sources (MYPP, 2012).

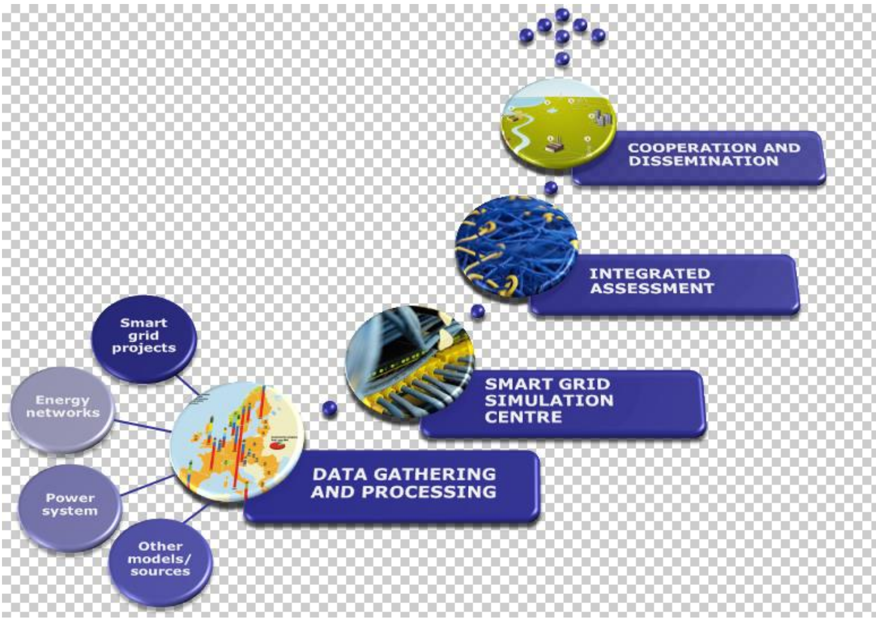

Figure 2. Efficient power processing.

2.3 Efficiency: Global Warming

Prior to the use of the smart grid, mankind was in danger of quickly destroying the ozone layer. The old and inefficient power transfer and distribution systems lead to the excess release of CO_2 and house gas emission. However, with the modern smart grid the enhanced Transmission and Distribution (T&D) systems have the ability to provide power to an area that has a higher demand. Because of this concept power plants no longer have to burn excess energy. As a result of these plants burning less energy, less CO_2 and house gases are released into the ozone layer, and the earth's atmosphere will be better preserved for future generations. In addition, the smart grid allows the use of renewable energy sources, which require no fuels to be burned. This means that one day when the smart grid is made up solely of RES's, that no house gasses or CO_2 will put into the Ozone. Finally the smart grid helps the global warming issue by raising the efficacy in power distribution, causes less energy to be lost in the distribution of power, and allows for modern developments such as electric cars.

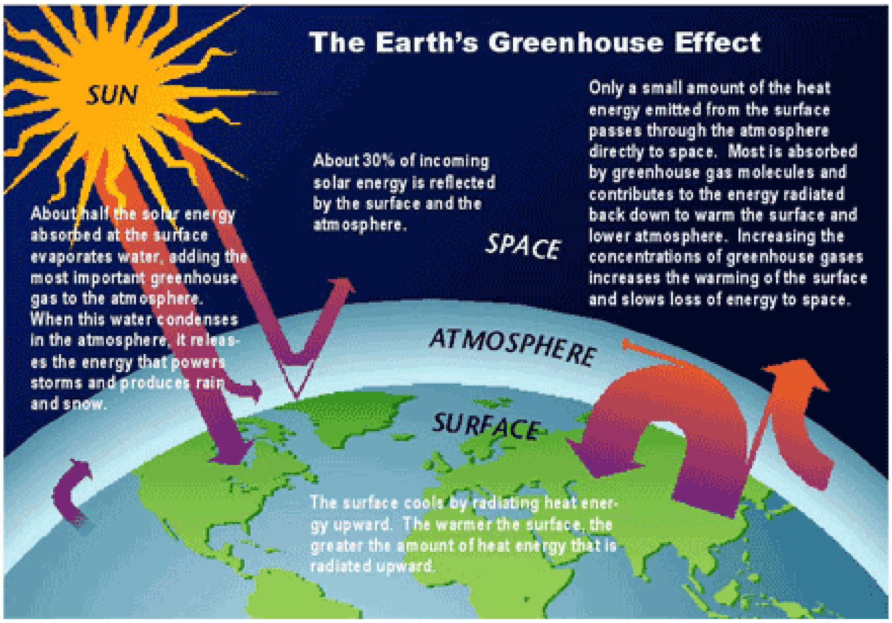

*Figure 3.*The Earth's Greenhouse effect.

2.4 Net-Metering

In 2011 there were 37.290.374 Advanced ("smart") Metering Infrastructure (AMI) installations made by 663 US electric utilities, 33.453.548 are residential, 3.682.159 are commercial, 154.660 industrial and the transportation allocation are 67 as shown in Table 1 (EIA FAQS, Jan 2013).

Table 1.

Number of AMI Installations by Customer Type.

Utility Type	utilities	Residential	Commercial	Industrial	Trans	Total
Investor Owned	73	25,891,279	2,886,498	78,688	4	28,856,496
Cooperative	311	5,017,654	495,609	47,667	0	5,560,930
Municipal	84	1,116,675	149,323	4870	0	1,270,868
Public & State	24	1,427,940	150,729	23,434	3	1,602,106
Totals	493	33,453,584	3682,159	154,660	7	37,290,374

AMI includes metering that can facilitate the communication between the customer and the utility companies, and its can provide all the required data that is need to be collected by all the network nodes because of their capability of using two way data communication. Not only does this increase the reliability and security of smart grid, but net-metering also can help in load distribution. The concept of Net-Metering is also an electrical policy for people who have their own power production units such as a Solar cell, Wind turbine, or Fuel cell. These people can get a retail credit when they feedback their extra power to the grid. There are two rate options for customers to choose from: either non time differentiations or a time of use rate. The choices depend on the service provider, the service availability, and the future potential.

The eligibility of net-metering varies because each state has different minimum power production regulations for each of its sectors. Forty three states took the initiative by regulating policies and rules for net- metering, to raise the efficiency of renewable energy contribution to the grid with the absence of federal leadership. For example, the minimum capacity in Alaska and Arizona is 25KW, in Colorado and Georgia 10KW. In some states the customer can sell all of his or her energy production to the network. Most of the RES systems are eligible for net-metering in all states and the applicable sectors are industrial, commercial and residential. So, net-metering is a symbiotic system that serves all the beneficiaries. Table 2 shows Incentives and policies for some states that had adopted net-metering policies and rules according to the Database of State Incentives for Renewables & Efficiency DSIRE (2012).

Table 2.

Incentives and policies for some states that had adopted net-metering.

STATE	Eligible RE	Sys. Capacity limit	Aggregate capacity limit
AK	All	25KW	1.5% average retail demand
AZ	All	Not specified but not more than 125% of customer total load	No limit specified
AR	All	300KW for non- residential 25KW for residential	No limit specified
CA	All	1MW and 5MW [1]	5% of aggregate peak demand
CO	All	25KW for non- residential and 10KW for residential	No limit specified
DC	All	1MW	No limit specified
FL	All	2MW	No limit specified
GA	PV, Wind, Fuel cells	100KW for non-residential 10KW for residential	0.2% of utilities peak demand during previous year
NC	All	1MW	No limit specified

2.5 Smart Grid: Security Issues

As the smart grid is still young, the networks unfortunately have not done a lot in the way of security. The device used to report each consumer's power consumption on the smart grid is called a smart meter. This smart meter is a computerized device containing a processor, nonvolatile storage, and communication facilities.

[1] For systems operating under the bill credit transfer program authorized by Public Utilities Code 2830, System must be owned by, operated by, or on property under the control of, a local government or university.

The smart meter is also connected on a server. Meters are built on easily obtainable commodity hardware and software and will be subject to many or all of the maladies of internet life. Some of the information stored in the smart meter can reveal private information about the consumer due to the meters power consumption signature, for example television watching.

In addition, it is ambiguous as to how privacy laws apply to these situations. Hacking is the next problem with the computerized smart meter (McDaniel & McLaughlin, 2009). A hacker who compromises his or her smart meter to show a higher amount of generated energy will receive a larger financial credit. This type of fraud accounts for as much as $6B a year. It is so easy to manipulate that a consumer can make a physical meter run backwards by tacking it from the socket and turning it upside down, thus giving themselves a credit. Frauds begin small like the quickly turn into large full scale computerized assaults.

Figure 4. Security connection.

2.6 Smart Grid Economics

The smart grid allows options for economic growth because of the access it provides to green RES's. From a financial point of view green power can offer organizations a variety of benefits such as: environmental, stakeholder relations, economic development, and national security. It will also provide a hedge against risks posed by electricity price volatility. Purchasing electricity generated by RES may provide the buyer protection against unstable or rising fossil fuel prices, for example through long-term, fixed-price supply contracts directly with developers or generators. Organizations can also encourage stable electricity prices by supporting new renewable power resources on the local grid; therefore, these organizations diversifying the energy mix with resources that are not subject to the rise and fall of fuel costs.

On-site renewable generation can reduce the risk of disruptions in fuel supplies, resulting from transportation difficulties or international conflict. To address global climate change and regional air quality issues, federal and state regulations could effectively increase the price of conventional electricity, making green power financially more attractive and it will be additional environmental regulation. Economic development and National Security, stimulate economies, increase fuel diversity, and reduce infrastructure vulnerability. Green power can be priced differently from standard power sources. It has usually been more expensive than conventional electricity sources, largely due to the relative newness of renewable technologies and their gradual diffusion into mainstream markets, compared with conventional electricity. The actual price for green power depends on a number of factors, including the availability and quality of the resource, manufacturing capacity and world demand for the technology, the availability of subsidies to encourage green power, and the quantity purchased and terms of the contract (Guide to Purchasing Green Power, 2010).

2.7 Programs and Goals

The Federal Government agreed to cover up to 50% of the cost of the new smart grid investment by establishing two grant programs, Smart grid Investment Program (SGIP) and the Smart Grid Demonestration Program (SGDP). The two federal programms provided $11B to moderenize the grid accelerated by the American Recovery and Reinvestment Act (ARRA) of 2009 with a maximum of $200M for each project. There are 99 smart grid investment grant projects with a total budget of about $8 billion. The federal share is about $3.4 billion as shown in figure 5 (Hicks, 2012).

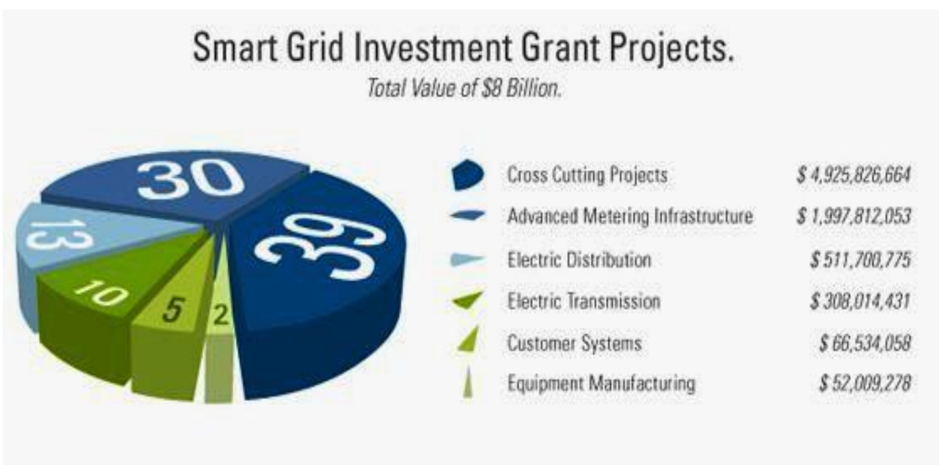

Figure 5. Smart grid investment grant project.

The research and development program (R&D) within the US Department of Energy vision is that by 2030 the grid to contain high intelligent systems that can provide high security, efficiency, reliability, and environmentally conscious. The Smart Grid (R&D) programs support the Goals of (OE) in developing a high performance grid and deploy an advance market for Transmission and Distribution (T&D) using High technologies. Implement a power grid can secure the national economy and reduce the carbon emission and achieving the president goal of producing 80% of America's power from clean sources. The Office of Electricity Delivery & Energy Reliability (OE) defines the smart grid by the following points in order to achieve the goals of smart grid by 2020:

- Customer participation
- Integration of all generation and storage options
- New markets and operations
- Power quality for the 21st Century
- Asset optimization and operational efficiency
- Self- healing from disturbances
- Resiliency against attacks and disasters.

The goals to be achieved by 2020 are applicable to commercial micro grid, self-healing grid, and high penetration of Distributed Energy Resources (DER), Demand Response (DR), and Plug-in Electric Vehicles (PEV) in distribution grid (Smart Grid R&D, 2012).

CHAPTER 3

Renewable Energy Sources (United States)

3.1 Introduction

The term green energy is used in a number of different ways. In the broadest sense, green energy refers to environmentally preferable energy and energy technologies, in all forms. This definition of green energy includes many types of power, from solar photovoltaic systems to wind turbines to fuel cells for automobiles. From a financial point of view, green energy can offer organizations a variety of environmental, stakeholder relations, economic development, and national security benefits. It will also provide a hedge against risks posed by electricity price volatility. Purchasing electricity generated by RES may provide the buyer protection against unstable or rising fossil fuel prices, for example through long-term, fixed-price supply contracts directly with developers or generators. Organizations can also encourage stable electricity prices by supporting new renewable energy resources on the local grid, thereby diversifying the energy mix with resources that are not subject to the rise and fall of fuel costs. On-site renewable generation can reduce the risk of disruptions in fuel supplies, resulting from transportation difficulties or international conflict. To address global climate change and regional air quality issues, federal and state regulations could effectively increase the price of conventional electricity, making green energy financially more attractive and it will be additional environmental regulation. Green energy generates much less pollution than conventional energy and produces no net increase in greenhouse gas emissions, helping protect human health and the environment.

There are many other benefits for green energy such as, meets organizational environmental objectives, allows people to demonstrate civic leadership, generates positive publicity for many sectors such as government and business, improves employee morale, provides a wide array of energy products and service options, grows economic development, strengthens national security because of its speedy energy recovery ability, increases fuel diversity, reduces infrastructure vulnerability, and will potentially lower prices of energy. Green energy can be priced differently from standard energy sources. It has usually been more expensive than conventional electricity sources, largely due to the relative newness of renewable technologies and their gradual diffusion into mainstream markets, compared with conventional electricity. The actual price for green energy depends on a number of factors, including the availability and quality of the resource, manufacturing capacity and world demand for the technology, the availability of subsidies to encourage green power, and the quantity purchased and terms of the contract (Kateeb, Burton, El-Bathy, and Almansour, 2012).

3.2 Solar Energy

Solar energy, which is inexhaustible and produces zero pollution, is the optimal energy that people are looking forward to. Solar energy systems can be configured to almost any size from a few kilowatts up to several megawatts. Solar energy can be converted in two different ways. The first method utilizes the heat from the sun rays and uses cells located at Concentrated Solar Energy Plants (CSPP), in order to convert the suns thermal energy into a heat fluid, which produces steam, which then spins a turbine to produce energy. The second method of solar energy conversion utilizes the photoelectric effect. This process involves the conversion of the light from the sun rays and Photovoltaic (PV) cells in order to translate the sun's energy directly into electricity. This second method is the main form of solar power.

PV effect is created when dissimilar materials are exposed to light and then generate electrical energy. In 1839 French Physicist, Alexander-Edmond discovered the very first PV effect. Then, four decades later Charles Fritts created the first solar cell by coating selenium in a thin layer of gold. This original semi-conductor was found to have an efficiency rate of only one percent (Vasileska and Klimeck, 2010). The next PV cells utilized a silicon doped semi-conductor that is extremely sensitive to light absorbency and thus were more efficient. Today there are many types of PV cells: the Homojunction device, the Heterojunction device, and p-i-n and n-i-p devices. Typically, amorphous silicon thin-film cells use a p-i-n structure, whereas cadmium telluride (CdTe) cells use an n-i-p structure. The basic scenario is as follows: A three-layer sandwich is created, with a middle intrinsic (i-type or undoped) layer between an n-type layer and a p-type layer. This geometry sets up an electric field between the p- and n-type regions that stretches across the middle intrinsic resistive region. Light generates free electrons and holes in the intrinsic region, which are then separated by the electric field (US Department of Energy, Energy Basics). The PV cell serves two main purposes for solar energy: it generates charge carries in light absorbing materials, and then separates those charge carriers to a conductive contact to create an electrical current, thus producing energy.

On-site PV systems are comprised of solar panels which are connected to a DC/AC inverter, which runs either to the equipment or a storage battery. Also, the panels themselves and other electrical components will be mounted to a rack system. PV Systems may be situated on schools, homes, community facilities, and commercial buildings. These systems can be integrated into a building, displacing other building material costs, such as for roofing, shingles, or car park shading. PV installations are growing rapidly in developed countries, but the US lags far behind Germany and China in this regard. These two countries lead the rest of the world in tidal generating capability of PV energy systems. With regard to installed capacity, Germany is clearly the leader, holding more than 85% of Europe's total capacity, in the year of 2012 Germany added 8.161GW which brings the total capacity of installed PV to over 32GW (Mathias and Mutschler, 2013). Figure 6 shows different types of solar cell and their uses.

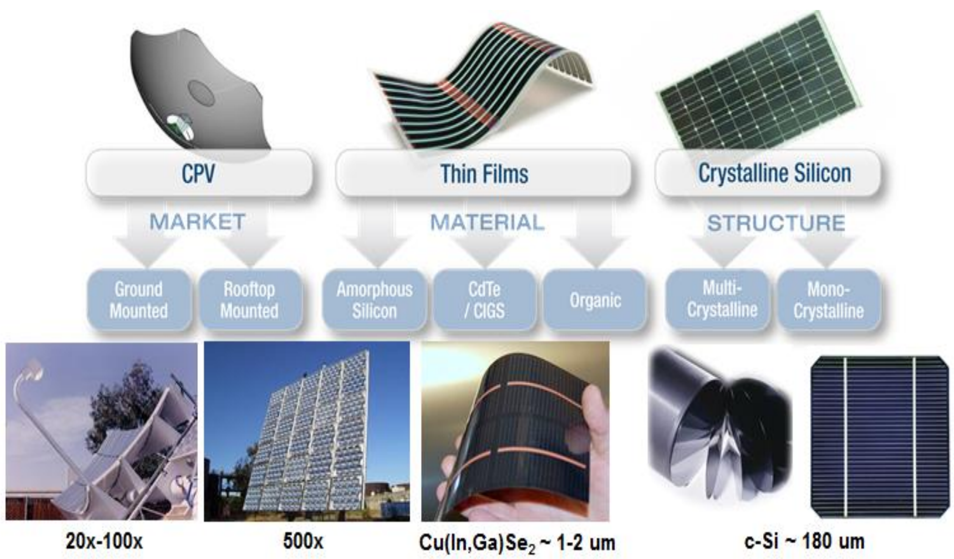

Figure 6. Different type of solar cells.

In addition, as for the cost aspect, current literature indicates that the future of PV dedicated conversion systems is in the adoption of transformer less topologies, because using a transformer increases the weight, size, and cost of the PV system, which in turn reduces with additional benefits in terms of conversion efficiency. In PV transformerless systems, the witching converter has to be designed not only for high efficiency and low Total Harmonic

Distortion (THD) but also to guarantee low ground current injection. The best locations in US for the PV solar resources are shown in figure 7.

3.2.1 Solar energy advantages. There are many advantages of solar energy such as the inexhaustibility of solar energy, zero environmental pollution, it is without geographical restrictions, and it comes with the great convenience of installing it anywhere. PV cells can be used as independent energy systems Microgrid and also can be connected to the main power grid. In addition, if certain issues are resolved such as cost reduction in maintenance and fossil fuels, reduction of low energy density

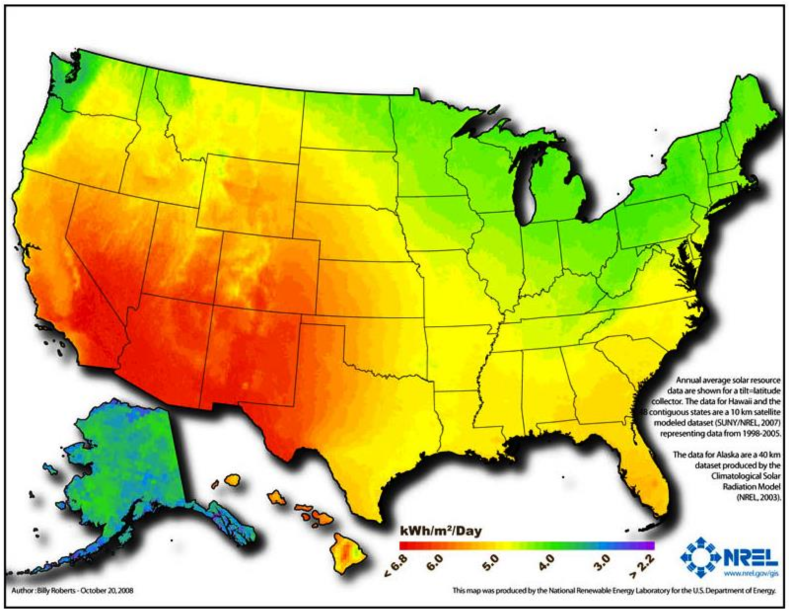

Figure 7. US PV Solar resources Map.

of the sun that requires large area for the solar energy to be harvested, the ability to change the radiation strength in a twenty four hour period because the highest energy generation in solar energy occur during the sun peak hours which vary from place to another according to the geographic nature and the climate, and a solution to the problem of smooth power, then solar energy systems can be adapted and applied to Distributed Resource (DR) systems. This will provide efficient access to solar energy for people living in rural areas.

3.2.2 Solar energy disadvantages. The main area of difficulty is with energy loss. The main source in which energy is lost is in the converter switching and conduction loss, as well as the energy losses in the output filter. This problem can be addressed with more sensitive and efficient PV cells that conduct and retain more of the sun's energy. Another disadvantage of solar energy lies in the cost infrastructure. Even though, there has been a drop in crystalline cells' prices in 2012. The pay-back plan benefit of tariffs for the produced energy still remains high with respect to the forecast for future years (Kateeb, Burton, El-Bathy, and Almansour, 2012). Figure 8 shows clearly that PV cost is the highest among all other RES in US despite the offshore wind not yet involved in RESs.

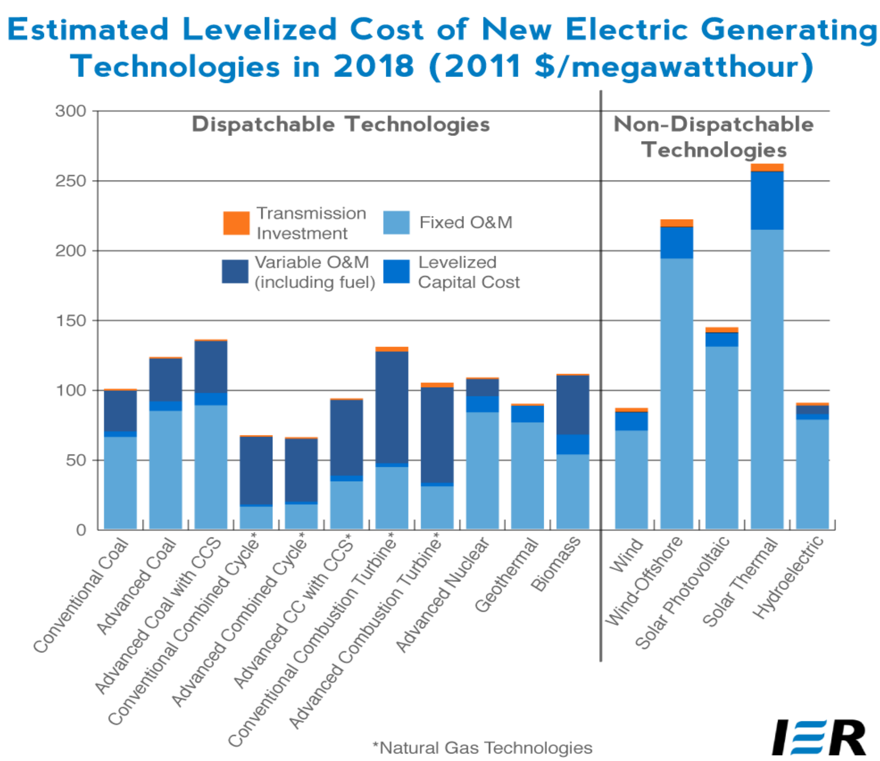

Figure 8. Estimated Levelized Cost New Energy generation Technologies in 2018.

3.3 Wind Energy

Wind energy has been implemented by humans since the beginning of time. As early as 500BC, the Egyptians used wind energy to move their boats down the Nile River. At the same time, countries in the Middle East and Persia used wind energy to grind grain. As time went on, people around the world began to use wind mills for food production and draining large bodies of water. Then the industrial revolution happened and larger windmills were designed in order to generate electricity. The use of windmills to generate energy has always been directly connected to the cost of fossil fuels. When fossil fuels are inexpensive, wind energy is at low point; however, when the price of fossil fuels rises, people become more interested in developing wind energy as a means of energy (History of wind energy).

Wind energy is a tremendous renewable energy**.** The comparative advantages of wind energy are embodied in: environmental protection, renewable energy, no fuel consumption, and no polluting the environment**.** A wind farm can be built anywhere. It can be built on the beach in shallow water, in a desert, on a mountain, or on any area of stable land.

In addition, wind fields are one 100% environmentally friendly. They do no damage to the land in which they are constructed on. The wind turbines themselves usually require approximately one acre of land per each turbine, each turbine is approximately 150ft high, and a turbine needs wind with an average speed of 15Mph. A typical small unit turbine provides 100kW or less, whereas large turbines range from 500kW to more than 3MW ((Kateeb, Burton, El-Bathy, and Almansour, 2012).

Most wind energy is applied in DR systems. This energy source is readily available, but there are still many key technological difficulties to be resolved; Such as the sitting, the lack of stability in the wind effecting energy generation, the costly economics of wind energy generation equipment, and the equipment relation to the single capacity issue (Annual Energy Outlook, 2012).

However, modern wind turbines are a higher density energy source than direct PV conversion. Based on 2012 production levels, wind energy sector added 44.7GW that increased the total installed capacity in the world 19% to be 282.5GW. However, the EU still at the top of the installed wind energy by 37.5% of the total followed by China with installed capacity off 26.8% then US by 21.2%, India 6.5% and Canada with 2.2%. Germany now at a rate of 31.31GW and Spain was at a rate of 22.8GW. These two countries were generally acknowledged to be the EU leaders in total wind energy generation of 106GW. If wind energy development continues at this rate wind energy would generates up to 16% of Europe's electricity by 2020 (Wind in power 2012 European statistics, 2013).

On the other hand, in the US, total estimated wind energy capacity exceeded 60GW in 2012 and is growing explosively from 2011 levels which put US at the top of world in producing wind energy. The Horse Hollow Wind Energy Center at The Roscoe wind farm, in Roscoe, Texas is believed to be the world's largest wind farm. When it was completed its output levels were about 735MW, and it owned 420 turbines across 19k hectares (190Km^2) in Texas. Figure 9 shows the Midwest of the US in general is the best resource for Wind energy. While wind energy currently accounts for more than 3.2% of US electricity generation, the total amount of electricity that could potentially be generated from wind in the US has been estimated at 10.8 TW/h annually—three times the current total electricity generated in this country (AWEA U.S., 2013).

Funding for wind energy is a key issue in US politics. A 2.2 cent per kW/h Production Tax Credit (PTC) for the initial ten years has been issued for organizations that generate wind energy. This credit was set to expire at the end of 2012 but then was extended to the end of 2013. Congress continues to go back and forth on the value and time line of the PTC for wind energy. In addition, the majority of funding right now for wind energy comes from the government as businesses finds the return on wind energy risky (Union of Concerned Scientist, Jan, 2013).

Some of the most relevant goals of present research include an increase in the energy production of each wind turbine (more than 5MW), an increase in the penetration of small wind-turbine systems (tens to few hundreds of kilowatts), and the creation of wind plants or farms whose behavior with respect to the grid emulates that of traditional oil and gas powered plants. The realization of this final goal may be possible due to reliable wind forecasts and proper control strategies. Research is also being conducted on wind turbine size. The increase in wind turbine size involves research on high energy converters based on modular technology, or multilevel, reliability, and on the associated control problems (Kateeb, Burton, El-Bathy, and Almansour, 2012).

3.3.1 Wind energy advantages. Wind energy has been used for centuries in many ways, for example: irrigation, crop grinding, and driving ships. For the last two centuries it has been used to produce electricity globally. It is one of the most promising renewable energy sources; it is tremendous, ubiquitous, renewable, and clean. By the end of the second half of 2012, the United States alone had installed a wind energy capacity that reached 60GW through 39 states in addition to Puerto Rico. Wind energy contribution adds more than 3.2% to the smart grids total energy generated in the US during the year of 2012.

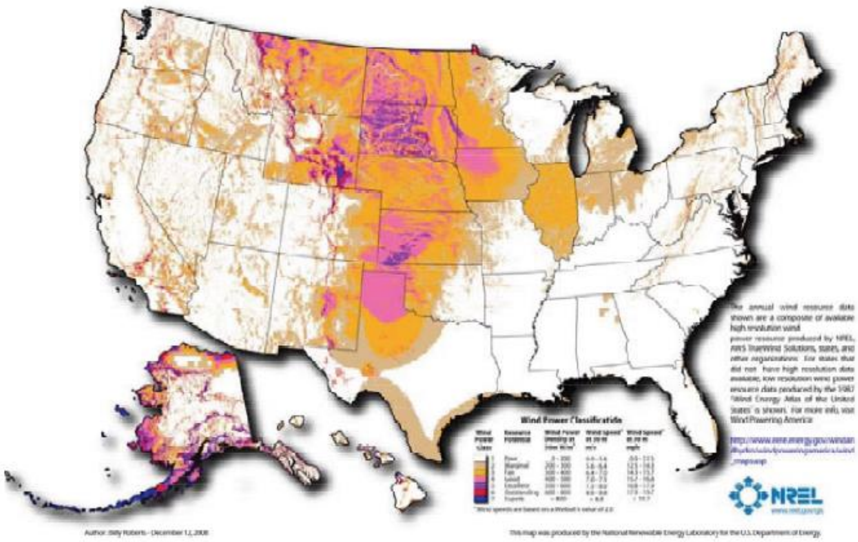

Figure 9. US Wind Resource Map.

The rapid development in wind turbines technology raises the efficiency and the capacity of each turbine. During the second quarter of 2012 alone 629 new wind turbines were installed in the United States. The sizes of these turbines vary from 250KW to 3MW. Each of these turbines has an average generation capacity of 1.91MW. With the high cost of energy still an issue, most of the wind energy lays on government subsidies (AWEA U.S. Jan 2013).

However, the government expanded the PTC to run all the way through 2013, which will have a positive influence on the wind industry. If the PTC had been cancelled, the head of VESTA Company, the operator largest wind turbine in the United States, predicted that the US wind industry will fall by 80% at the end of 2012 (Reuters, 2012).

3.3.2 Wind energy disadvantages. One unfortunate caveat associated with this RES is that wind can stop blowing at any time without any warning, so the wind energy is inconsistent and unpredictable. Another disadvantage of wind energy comes from a financial aspect. The 20 % by 2030 plan aims to have 20% of the US electricity generated by wind energy by 2030 (WEA, May, 2008).

It is predicted that the carbon emission tax will only be reduced by 2%, and to obtain this reduction $850B will need to be invested initially. If this “20% by 2030” target was met would raise taxes enormously for the consumer to compensate for the cost of the equipment and construction. Robert Bryce, senior fellow at the Manhattan Institute predicts the tax on carbon dioxide that being removed between, $45 to $54 per ton, for the consumer, the tax will skyrocket electricity prices about 48%.

3.4 Geothermal Energy

Geothermal resources require three elements to generate energy: heat, fluid, and permeability. Also, there are three different technologies for harnessing geothermal energy. Dry steam plants take fluid directly from the geothermal reservoir, run it through a rock catcher, and then the dry steam drives a turbine to generate electricity.

The second type of plant is a flash steam plant. The flash steam plant technology requires a high pressure fluid of at least 182°C. This fluid enters a lower pressure tank at the surface of the reservoir and the fluid flashes, separating the liquid and the vapor. The vapor travels to the turbine to drive it and generates electricity. The remaining liquid can be transferred to another tank to be flashed again in order to generate more energy.

The third way to generate geothermal energy is with a binary cycle energy plant. This cycle involves another fluid with a lower boiling point. The geothermal fluid in a binary cycle is below 204°C. The two fluids interact in a heat exchanger where the geothermal fluid heats the lesser boiling fluid causing it to flash. Then, the flashed vapor goes to the turbine and drives it to generate electricity. This is known as a closed loop system. Figures 10, 11, and 12 are showing different types of geothermal plants.

The installed geothermal energy capacity in the USA is currently 3187MW more than any other country in the world. About 50% of the geothermal energy is Dry Steam plants with 1585MW installed capacity.

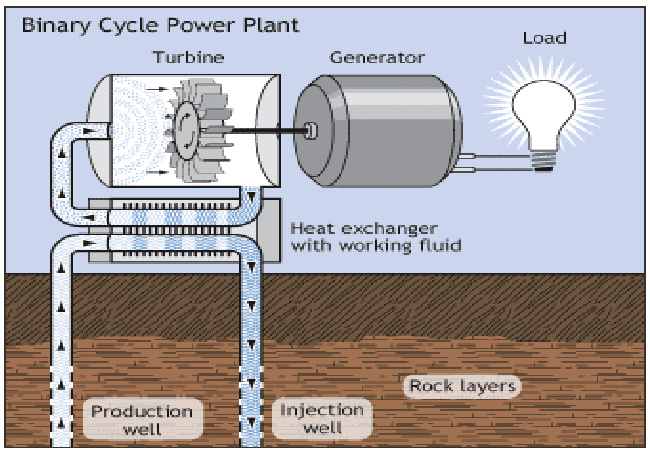

Figure 10. Binary Cycle power plant.

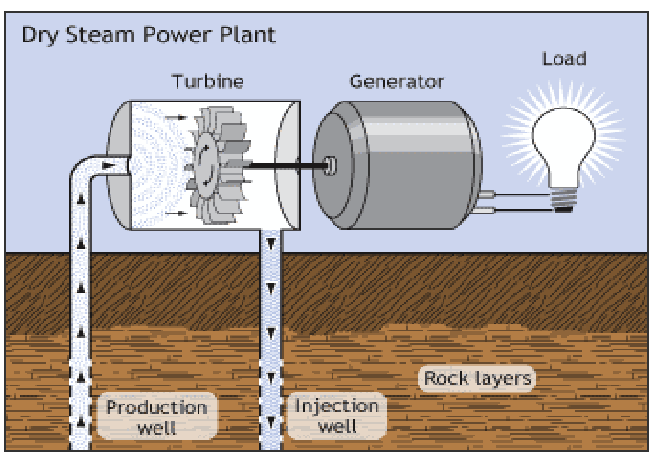

Figure 11. Dry Steam power plant.

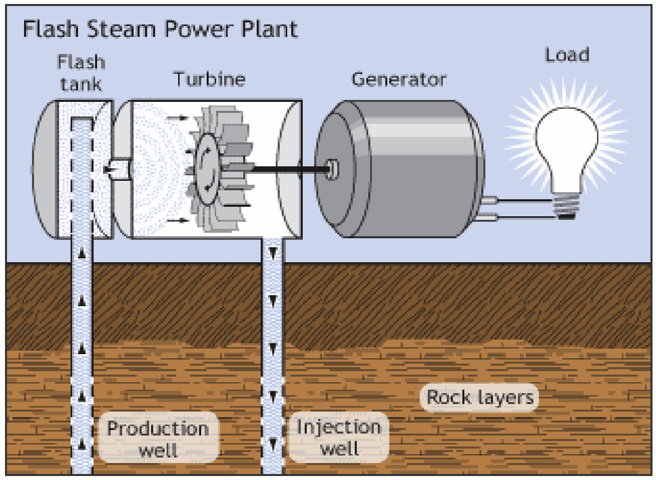

Figure 12. Flash Steam power plants .

Currently, geothermal companies are developing 1779 - 1821MW of confirmed (Planned Capacity Addition) projects in the US. Figure 13 shows the growth of geothermal energy in the US from 1960 to 2012, alongside the same statistic for the rest of the world combined (GEA, 2012).

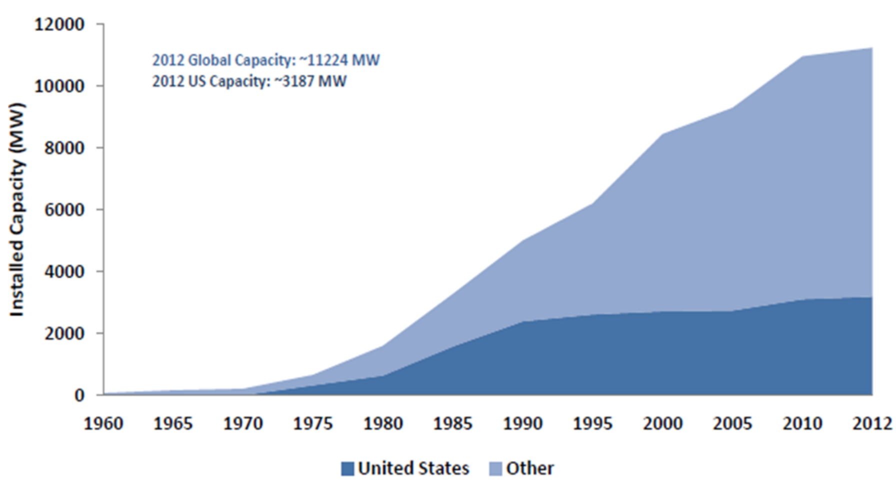

Figure 13. US geothermal installed capacities from 1960 to 2012.

The Department of Energy's cost goal is less than 5¢/kWh for typical hydrothermal sites, and 5¢/kWh for enhanced geothermal systems with mature technology. Recent Massachusetts

Institute of Technology (MIT) analysis shows for long term potential for 100.000 MW installed in Enhanced Geothermal Energy Systems (EGS) by 2050, and it will be cost-competitive with coal-powered generation (Kateeb, Burton, El-Bathy, and Almansour, 2012).

EGS have a few challenges, such as site selection, exploration techniques for EGS, and EGS paradigm shift from hydrothermal. Creating EGS in a variety of geologic environments creates a subsurface fracture system to enable extraction of heat. This requires sufficient flow rates (80kg/sec), heat exchange volume (recoverable energy), and surface area recovery rate, as well as a minimal loss of injected fluid.

There are very few EGS field experiments that have been conducted worldwide; therefore, experimental evidence of EGS reservoir productivity is not well established, and heat exchange volume and longevity is lacking (Kateeb, Burton, El-Bathy, and Almansour, 2012). Figure 14 shows the main steps for EGS, starting from locating the site, creating the reservoir, and ending with completing and verifying circulating loops.

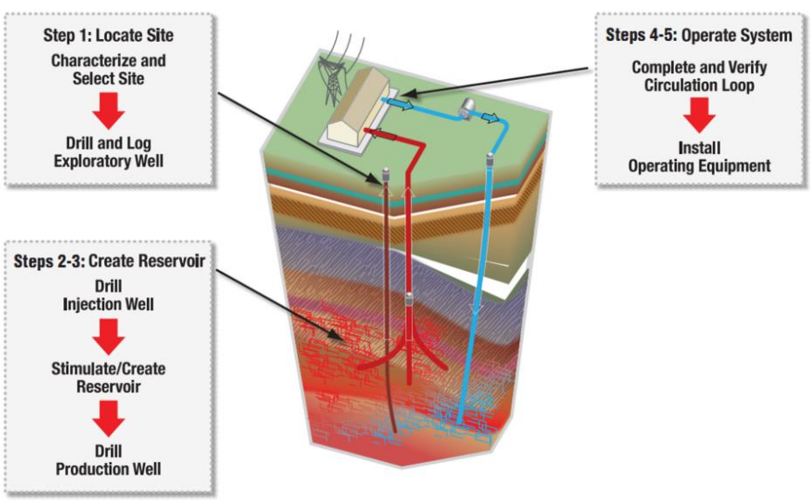

Figure 14. Enhanced Geothermal System Development Sequence.

3.4.1 Geothermal energy advantages. Geothermal energy is a reliable and sustainable resource. It can operate twenty four hours seven days a week, which can produce base load energy. It is a flexible energy because it can be ramped up and down depending on the demand which integrates the grid and supports intermittent resources such as wind and solar. The generators actual energy output is 90% or more which means it can compete with base load resources such as burned coal and nuclear power. Binary plants are emission free which makes them environment friendly. In addition, the Nevada Geothermal Council (NGC) states that 300MW of geothermal energy can replace 4.5Mb of oil (the equivalent fuel used by 100k cars) and, it will avoid the emission of 2.25 million tons of CO_2 annually. Geothermal energy supports the national economic plight by creating jobs (GEA, Feb, 2012).

3.4.2 Geothermal energy disadvantages. As per the Geothermal Energy Association, geothermal plant construction is initially very expensive. The cost for a land plant in US is $2500pKW installed. This means that three to five thousand dollars is needed just to get a small plant up and running. Also, maintenance and operation costs are high. They range from $0.01 to $0.03pKWh. Also, land surface sustainability can be affected by the geothermal plant if the water is not injected back to the reservoir. Also, there could be some dangerous traces of heavy metals such as Mercury, Arsenic, and Boron, which can be dangerous for humans and the environment. These substances need to be handled and disposed of in a proper manner.

3.5 Biomass

Biomass is the only renewable energy source that can substitute oil products in the near term. As per US Department of Energy DOE, the country spends $1B a day on imported oil. That was one of the reasons that US approach the biomass projects development which will redirect some of the US expenses internally on development and creating more jobs. The Energy Efficiency and Renewable Energy Biomass program is one of the programs under US DOE s focused on forming cost share partnerships with key stakeholders to develop, demonstrate, and deploy technologies for advanced biofuels production from lignocellulosic and algal biomass. Figure 15 shows the primary pathways that the program's conversion efforts focus on in order to deconstruct biomass into intermediates and subsequently upgrade them into biofuels and bio-products.

In the biological and chemical sciences, systems based on biomass are being studied. There are several methods of producing energy using bio-materials such as garbage, wood, plants, waste, landfill gases, and alcohol fuels. One type of Biomass is plant. This material is burned in a boiler to drive a steam turbine to produce electricity.

This system is good for producing Combined Heat and Energy (CHP) at facilities with large thermal loads. These biomass projects are best suited to locations with abundant plant biomass resources such as large forest areas or agricultural areas. These areas in the United States are seen in figure 16. Methane gas derived from landfills or sewage treatment plants is another bio product that can generate electricity. Methane gas also may be generated using digesters that operate on manure or agricultural wastes.

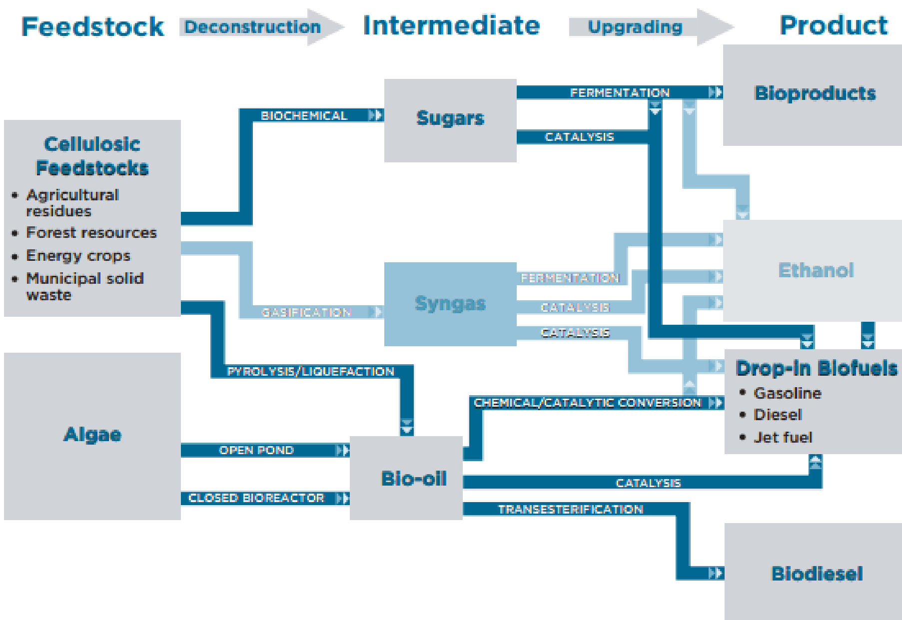

Figure 15. The primary pathways that the program's conversion efforts focus on.

The methane gas is then converted to electricity using an internal combustion engine, gas turbine (depending on the quality and quantity of the gas), direct combustion boiler and steam turbine generator set, micro turbine unit, or other energy conversion technologies. Most methane gas projects produce from 0.5 to 4MW of electrical output (Kateeb, Burton, El-Bathy, and Almansour, 2012).

3.5.1 Biomass advantages. The annually growth in biomass energy in US is 8.9% since 2004. This represents more than 20K direct jobs. This rapid growing in the biomass energy field will create more jobs especially in rural areas. The estimated growing use of biomass energy in the US can displace more than 30% of petroleum consumption.

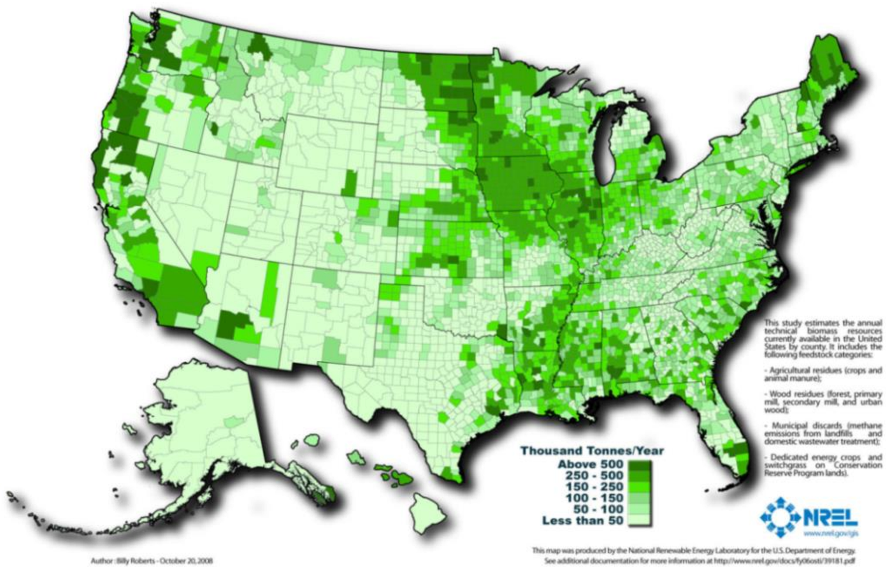

Figure 16. U.S. Biomass Resources, NREL.

So, biomass can stimulate the economy and reduce importing petroleum products such as ethanol, which can displace $20.9 billion a year based on gasoline priced at $2.4. Also, Emerging biofuels can reduce the Green House Gases GHG by 70% to more than100% (Replacing the Whole Barrel to Reduce U.S. Dependence on Oil, 2012). Table 3 shows a study conducted by Oak Ridge National Laboratory (ONRL) in 2011 showing the high potential of Biomass resources available in US (Union of Concerned Scientists, 2012).

Table 3

Assumption of available Biomass resources in US .

Feedstock	Available biomass (million dry tons)
Energy Crops	400
Agricultural Residues: Primary	180
Agricultural Residues: Secondary	25.5
Waste Materials: Urban and Mill Wastes	43.4
Waste Materials: Manure	58.9
Forest Biomass: Integrated Operations	40.9
Forest Biomass: Other Removals	12.6
Forest Biomass: Pulp	3.4
Forest Biomass: Thinnings	3.2
Total	767

3.5.2 Biomass fuel disadvantages. Biomass fuel can pollute the air if burned directly and not controlled correctly. The cost of producing biomass and converting it to alcohols is still very high. Also, the plants need to be built near the source. The sources are found in rural areas and therefore, the generated energy must be transported to the grid. This takes time and costs money. Also, the corn plants that are used to produce biofuels consume a lot of water for irrigation, which affect the water resources in dry areas. Another drawback is building the biomass plants. It causes deforestation and makes animals and people lose their habitats. The production of biodiesel relies on fossil fuels which cause pollution. Finally, the price of biodiesel is more expensive than fossil fuel (Mayes, 2009).

3.6 Fuel Cells

Fuel cells (FC) are another way of producing power by chemical reactions. They emit essentially no air pollution and are more efficient than other forms of generation, but they cannot be considered a renewable resource unless they operate on a renewably generated resource, such as PV or wind energy (Kateeb, Burton, El-Bathy, and Almansour, 2012). Fuel cells use hydrogen directly from fuels such a natural gas, gas, oil, etc. to react with oxygen in the air, then with the assistance of electrolytes, they form water and at the same time generate electricity. Materially it is a course from chemical energy to power. It is as simple and efficient as directly changing chemical energy into electrical energy, rather than the traditional thermal energy generation using chemical fuel energy (Kateeb, Burton, El-Bathy, and Almansour, 2012). There are several types of FC such as Polymer Electrolyte Membrane (PEM) Fuel Cells (figure 17), Phosphoric acid Fuel Cells (PA) (figure 18), Molten Carbonate Fuel Cells (MC) (figure 19), and Solid Oxide Fuel Cells (SOFC) (figure 20). PEM also called proton exchange membrane fuel cells delivers high-power density and offer the advantages of low weight and volume. PAFC uses liquid phosphoric acid as an electrolyte. The acid is contained in a Teflon-bonded silicon carbide matrix and porous carbon electrodes containing a platinum catalyst. MC fuel cells are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide ($LiAlO_2$) matrix. SO fuel cells use a hard, non-porous ceramic compound as the electrolyte. Higher temperature Fuel Cells [phosphoric acid FCs, molten carbonate FCs, and solid oxide FCs (SOFCs)] are often considered for stationary energy generation.

3.6.1 FCs advantages. Some of the fuel cell advantages are the great energy conversion efficiency, zero emissions, no noise, no vibration, the provincial water, stable and reliable energy output, with a strong ability to load changes. Research is needed for more key technology to improve the manufacturing level, increase the production scale, and improve the degree of automation and less cost.

Among the existing FC technologies, each type can be configured in a system focusing on the market segments that match its characteristics most favorably. Because of their quick start-up potential, low- temperature FCs [Alkaline FCs and Polymer Electrolyte FCs (PEFCs)] are being considered for portable, residential energy and transportation applications.

Because of their solid electrolyte, SOFCs are also considered for transportation applications by some car manufacturers or car suppliers. From the last year until now there are

1.700 fuel cell-powered forklifts deployed or ordered, 25 fuel cell buses placed or planned for transit service and more than 74MW of stationary energy installed or purchased.

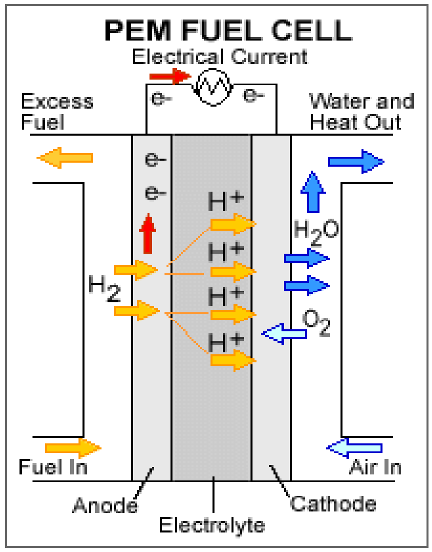

Figure 17. Polymer Electrolyte Membrane FC.

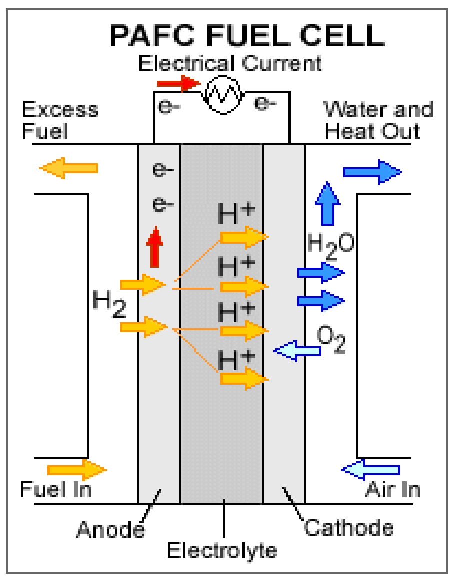

Figure 18. Phosphoric acid FC.

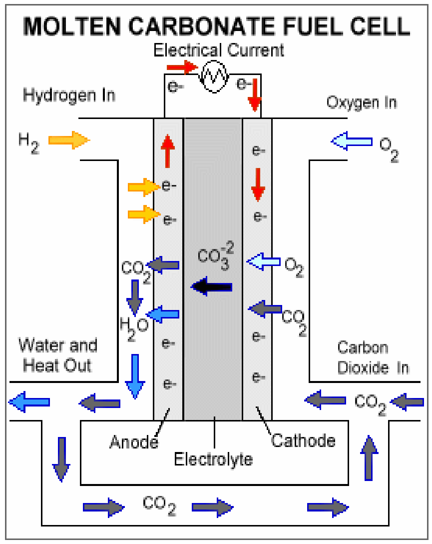

Figure 19. MCFC.

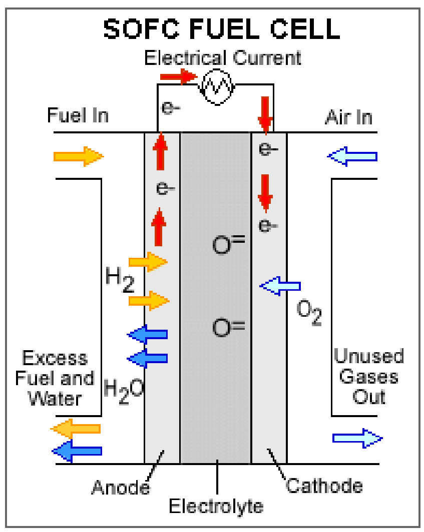

Figure 20. SOFC.

When the American Recovery and Reinvestment act took place, a sum of money was awarded to the US department of Energy (DOE). DOE decided to invest $42 million to further the advancement of fuel cells in the US. The idea was to popularize and install more fuel cells widely across the nation. Due to this investment over 1000 fuel cells got installed. They were used primarily in forklift applications and backup power systems. Success with this initial installation got other industries like the transportation industry interested in fuels cells.

Additional funds of close to $96 million got added to the project. Now, due to this new money, more fuel cells were installed. Because of this deployment of fuel cells, massive corporations such as Whole Foods, FedEx, Sprint, AT&T, Wegmans, Sysco, and Coca-Cola have demonstrated a budding interest in the implementation of fuel cells.

As a matter of fact, these industries have placed orders for over 1300 fuel cells to be utilized as backup power sources and ordered over 3500 fuel cell forklifts. Many jobs have been created and most importantly kept in the United States. High tech manufacturing jobs have been created by companies such as Altergy, Plug Power, and ReliOn.

Now, over a million hours of labor related to fuel cells has transpired and 1100 fuel cells have been installed. In addition, there has been a wide spread interest in these renewable energy assistants by major corporations across the US. On 12 May 85% of the Recovery Act funding was spent, resulting in these advantages for fuel cells see figure 21(Progress and Accomplishments in Hydrogen and Fuel Cells, 2013).

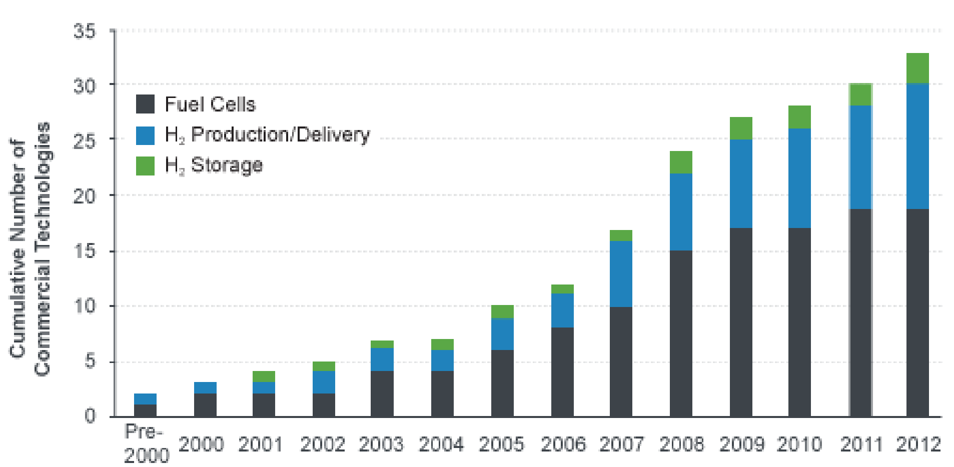

Figure 21. The commercially available products developed program funding.

3.6.2 FCs disadvantages. Considering the whole FC system, the gains in terms of both energy savings and pollutant emissions depend greatly on whether this whole FC system is well designed or not, and on whether global optimization has been performed on this system or not.

Accordingly, a great number of technological challenges have to be solved before efficient, competitive, reliable FC energy generators can actually be seen on the market.

3.7 Hydro-Wave Energy

Oceans cover approximately 75% of our planet's surface, and renewable energy comes from the planet in different forms: waves, currents, thermal gradients, salinity gradients, and tides**.** Until now, more than 1,000 patents have been dedicated to wave energy converters aimed at exploiting this energy**.** Wave Dragon, figure 22, is an overtopping device consisting of two wave reflectors, a main platform body, hydro turbines (low head type), electrical generators, and finally, energy electronic converters (AC–DC–AC)**.**

The Wave Dragon offshore wave energy converter is a slack-moored, floating overtopping device**.** The design of such a system has attracted many researchers who are active in different research fields to solve problems related to body and wave reflectors construction, hydro-turbines, energy electronics, electrical machines, and control (Kateeb, Burton, El-Bathy, and Almansour, 2012). The relationship between energy generated in kW, wave peak period in seconds and wave height are shown in figure 23. The higher and the longer the wave will yield in more energy generated.

3.7.1 Wave energy advantages. Wave energy is clean source of energy with negative pollution with no gas emissions. Dislike other RES like solar and wind; wave energy is predictable due to the consistent tidal cycle. Once the initial cost recovered the cost of generating electricity is low compared to fossil fuel and natural gas plants for long term. The plant can operate continuously for decades. The safety risks in wave generation are few. Wave energy requires no dam so, the power produced direct from the tidal movement and the outlet water will return back to the source.

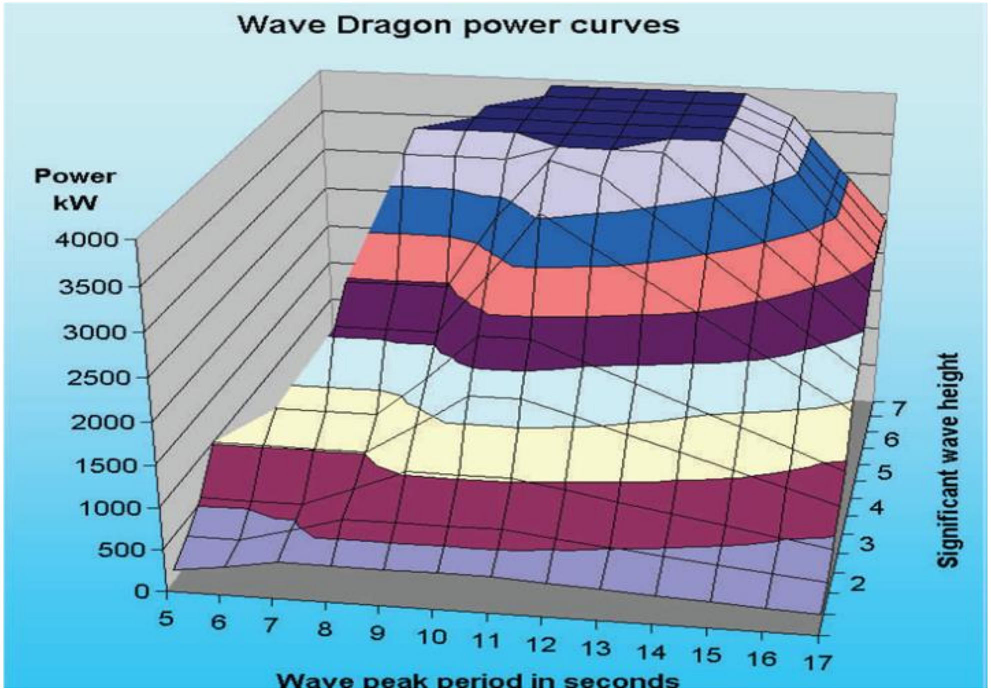

Figure 22. Wave dragon.

3.7. 2 Wave energy disadvantages. One of the most impacts of wave energy plant will be on the marine ecosystem and species that live in the water or onshore. The plant will take a big area of the sea which will force the species to immigrate and leave their ecology. The electrical cables can produce electromagnetic field around them which can affect sensitive species. The cost of connecting plants to the grid remains high due to the abundance locations. High salinity sea water can caused damages to the equipment and constructions on the long term (Fisher. C., Slater. M, 2010).

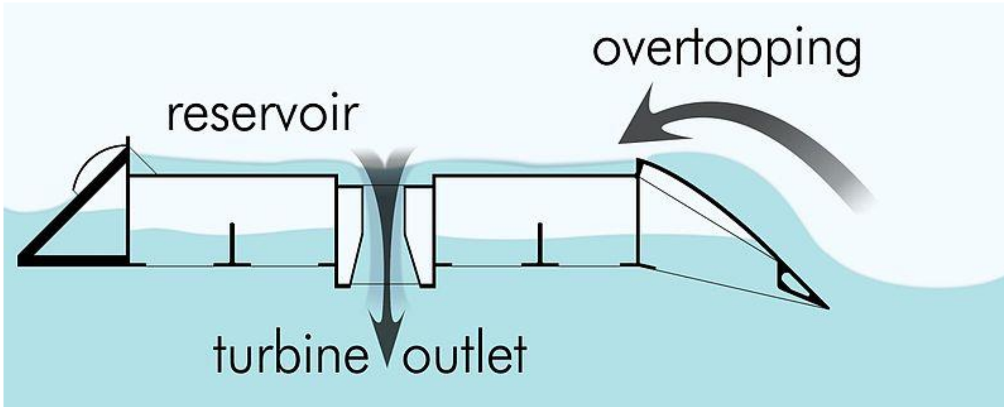

Figure 23. Wave dragon energy curves.

3.8 Challenges to RES Technologies and the Grid

A global concern about greener Earth is related to a better and efficient method to generate and transmit energy and electric power. With the initiation of renewable energy generators, a green smarter, more efficient and customer-friendly energy grid is essential. Smart grids represent the most useful and efficient way of integrating renewable energy generation in the main grid. Energy converters are the technology that enables efficient and flexible interconnection of different players (producers, energy storage, flexible transmission, and loads) to the electric energy system. Energy electronics is needed not only to connect RESs, distributed energy generation system (DPGS), and storage systems to the energy system but also to load, to regulation capability, and transmissions systems [High Voltage DC transmission (HVDC) and flexible High Voltage AC transmission (HVAC)] (Kateeb, Burton, El-Bathy, and Almansour, 2012).

As mentioned before, RESs are much smaller than traditional utility generators. The small size of the present RESs simultaneously presents new challenges and opportunities. To collect sufficient energy to meet the demand, the concept of energy farms has become well known. Farms of energy sources constitute their own grid, different in both scale and dynamic characteristics compared to the traditional utility grid. On the other hand, the small size of RESs makes it increasingly feasible to produce electric energy in countryside areas and other locations previously deemed economically infeasible. Connecting hundreds and thousands of RESs to the utility network introduces different dynamics to the system. If the distributed sources are not properly controlled, the grid can become unstable and even fail. The challenge of connecting a renewable source to the utility network is largely solved by electronic energy converters that handle two main tasks; first, maximum energy transfer and energy limit, secondly, active/reactive power control and energy quality control.

The relatively small size of many RESs makes it feasible to develop smaller-scale networks for geographically remote or isolated areas not previously served by a traditional utility network. Combinations of sources can be grouped together, forming a Microgrid. Issues such as load sharing, energy factor control, and energy quality management are common research themes today. Small-scale RESs for isolated, remote locations are generally more expensive than traditional systems. Smart Microgrids are usually operated with connection to distribution grids but have the capability of automatically switching to a stand-alone operation if faults occur in the main distribution grid and then reconnecting to the grid at a later time.

The safe operation in any condition (grid connected or standalone) relies also on good simulation tools to predict the behavior of the overall system considering the specific operation of the RESs. The operation of a smart Microgrid (figure 24) can result in higher availability and quality compared with strictly hierarchical management of energy generation and distribution. The security of the system can be improved by quickly reacting to short-term demand variations and redispatching energy feeds to final users. Such ability allows operators to reduce risks and consequences of blackouts while also avoiding the need to increase global production.

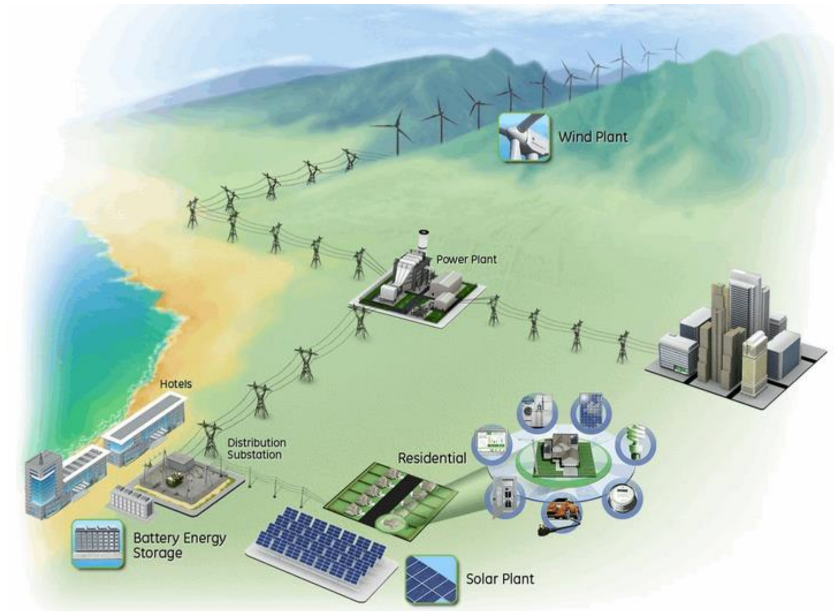

Figure 24. Electrical smart Microgrid.

Electronic energy converters are the essential commodities of RESs. Energy sources such as the PV module produce DC energy that must be converted to AC form to connect to the utility grid. In addition, RESs typically produce low levels of energy compared to traditional generation, so some means of collecting the outputs of many sources is required. Sources such as wind turbines operate at frequencies that are different from the grid, and speeds can vary significantly. Accommodating the differences in frequency is possible only through the modern electronic energy converter. RESs are more intermittent in operation than traditional generators, so it is common to supplement their operation with other sources energy converters provide the means to physically combine the outputs of different sources.

As renewable sources are being integrated to the grid, the DC transmission system is being revived as an alternative transmission scheme for several reasons. PV systems are inherently DC sources. In wind turbine systems, the DC link is a popular way to decouple the fixed frequency of the grid from the variable frequency of the generator. With state-of-the-art

DC transmission for crossing long distances and/or the sea, the skin effect losses of AC energy are eliminated, so cable losses are reduced (Kateeb, Burton, El-Bathy, and Almansour, 2012).

Oracle conducted telephone and online interviews with North American C-level utility executives in January 2010 as part one then they conducted another survey in March and April of 2011 after the US president call for generating 80% of America's electricity from clean energy sources by 2035 as a new national goal.

Found that today's US energy system has the following characteristics; dependent on foreign sources, subject to price volatility, increasingly unreliable, about 2/3 of source energy is lost, and produces 25% of the world's carbon emissions. Issues imperative for the transformation from the old to the new energy system define the end states, reduce new technology risk, and accelerate the adoption of all new outcomes and technologies. To have a sustainable energy system, the following should be satisfied and accounted for: carbon neutral, efficient, diverse supply options, minimal impact on resources, create sustainable jobs, accessible, affordable and secure energy. Oracle survey includes 152 utilities executive, the majority of them were in general manager and managing director positions with 53% the others were President, CEO or COO 22%, Owner/Partner 9%,VP/Assistant VP/Principal 6%, CIO and CTO 5%, CFO, Controller and Treasurer 4%, and EVP/SVP 1%. Here are some of the key findings for Smart Grid (tables 4, 5 and 6) for the next 10 years (Oracle Releases, 2011).

In table 4 improving service reliability, operational efficiency and implementing smart metering was the first priorities with 40% each. Developing demand response and energy efficiency was the second issue that those C-level utilities executives would like to set as priorities. Followed by updating physical infrastructure by 29% then offering real time pricing option with 26% these are the top five priorities for the next ten years according to the survey.

Table 4.

Smart grid Priorities

No	Smart grid priorities for the next 10 years	%
1	Improving service reliability and operational efficiency	40%
2	Implementing smart metering	40%
3	Developing demand response and energy efficiency programs	33%
4	Updating physical infrastructure	29%
5	Offering real time pricing options	26%

Table 5 shows the concern of smart grid components that will see wide-scale utility adoption most quickly for the next decade. Smart metering came at the top of components with 63% this has implemented very well in smart grid industry. Demand response and critical peak pricing was the second component with 48%, then the other components in different percentage but accommodation of plug-in hybrid electric vehicles was the least with 21% that leave a big why for the utilities company to answer, but of its big impact on the environment it should be one of the most quickly adopted components.

Table 5.

Smart Grid Components.

No	Utility adoption of smart grid component	%
1	Smart metering	63%
2	Demand response and critical peak pricing	48%
3	Smart distribution and/or transmission operation devices	38%
4	Integration of renewables	30%
5	Increase in smart sensors on the network	26%
6	Accommodation of plug-in hybrid electric vehicles (PHEVs)	21%

Table 6 includes the next big things for the utilities industry including RES in the utilities industry thing they liked to have. In terms of Energy Challenges, we can safely say security of the grid (secure supply and reliable infrastructure) is on the top of the list, followed by economy (economic development, energy price volatility and affordability) and environment (carbon mitigation, land and water use).

Table 6.

Next Step for Utilities Industry.

No	What is next big things for the utility industry
1	Renewables (including nuclear, solar, and wind power)
2	Energy storage and distributed generation
3	Automated meter readings
4	Rate-structure changes
5	More transmission lines
6	CO_2 legislation
7	Overall conservation efforts

CHAPTER 4

Saudi Arabia

4.1 Introduction

SA is a semi-developed country with a population of over 29M people. It is the largest country in western Asia with an area of 2.225MKm^2, with 3400Km of costal land, 2400Km on the west and 1000 Km on the east. The coastal area is humid most of the year ranging from 66% to 100 % humidity. 28% of SA is made up of desert land consisting of small nomadic populations. The climate is extremely hot with temperatures in the summer reaching 120F° and a minimal amount of rainfall at 9.9mm annually. This means that during the summer 23% of SA's electricity consumption goes towards air conditioning. There are three central cities: Riyadh, Jeddah, and Dammam. These cities are rich in both local and global businesses. SA's largest export is oil, owning 1/5 of the world's supply, and producing 12Mbpd. However, SA is far behind in developing a smart grid and RES. A lot of this is to do with lack of participation by both the government and the private business sector. Currently SA spends over $13B a year on generating electricity from oil. A combination of the government and the private sector is focusing on mainly developing wind and solar energies. It is estimated that $117B will be invested in RES in SA over the next 25 years.

SA is the largest consumer of petroleum in the Middle East, due to the high demand for transportation and electricity generation. In 2012, SA consumed about 3Mbpd domestically. This high rate is caused by the large industrial growth in SA and the subsidized prices. According to the Saudi electrical company, the total amount of generated power in 2011 was 190.280GW. This is an increase of 3.798GW since 2010. In addition, SA's electricity consumption is currently growing eight percent a year. SA currently has an installed capacity of 55GW and by

2020 the goal is to increase this amount to 120GW installed capacity. SA aims to generate 55GW of renewable energy by 2020, in order to free up fossil fuels for export. 41GW of the 55GW will be generated from solar energy. An additional 17GW of generated energy will come from future nuclear plants. Smart grid technologies are also under consideration in SA. This will allow an efficient and reliable way to control the energy in the future.

In addition, the potential for wind and geothermal energy is very high. There is more than enough wind to drive wind turbines, and SA lies on very geologically active peninsula. There are more than ten hot springs that have temperatures that range from 50C° to 120C° could be enough to generate electricity.

According to SA energy efficiency report SA's primary energy consumption per capita is 3.6 times higher than the world average, at 6.7 toe in 2010 compared with the world average of 1.9toe. Figure 25 shows the energy consumption trends by sector for the last 20 years.

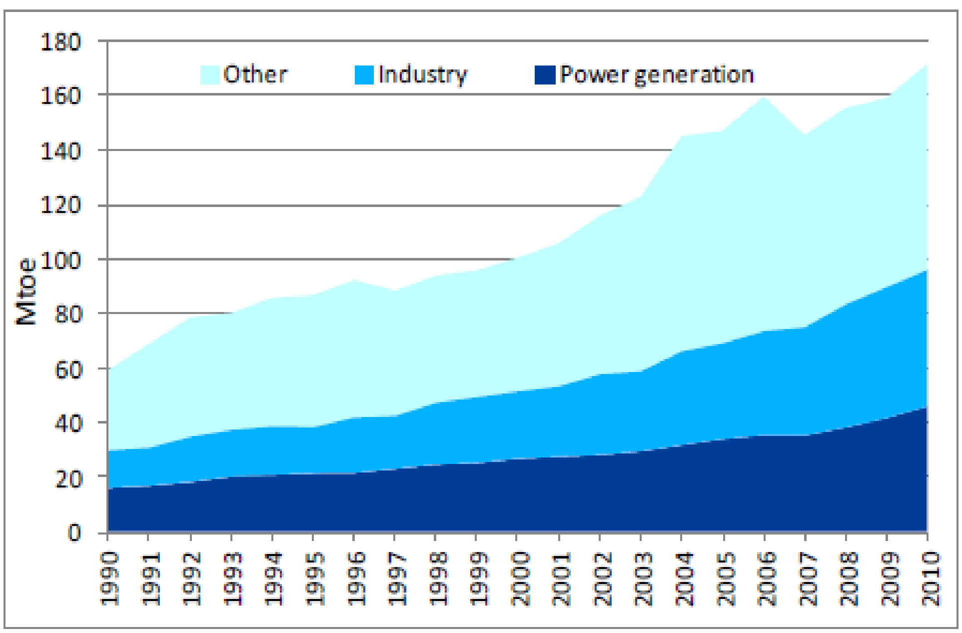

Figure 25. Consumption trends by sector.

4.2 Electricity Sector in SA

Electrical sector in SA has passed through many stages of development. Starting from 1961 when the first administration for running the affairs of electricity was established by the government of SA to supervise, manage and develop the electricity sector in SA. At that time the electricity in the kingdom was limited to some diesel generators in big cities such as Makah, Jeddah and Riyadh to light The Holy Mosques and government buildings. Several years later the government started the first 5th year plan in 1970. The council of electricity was established that year and they uniformed the first tariff system in that year. Even though, the tariff was too expensive at that time but the demand was high. After that the electricity sector start developing over the years with establishing four civil electrical companies; the eastern, the middle, the southern and the western regions. The web of electrical lines spread for thousands of miles to cover all the cities and villages in the country since then.

In Dec 1st 1998 the Saudi government unified all the electrical companies in one joint company under the name of "the Saudi company of electricity. Nowadays, the electrical in sector in SA managed and supervised by two ministries; the Industries ministry and Electrical ministry. In 2011 report by the Saudi company of electricity the power generated was about 51GW in a transporting network reach 49.700Km with a distribution network with 409.000Km supplying 6.3million customer in 12.256 cities and villages. The power demand in the last decades has increased in a massive way due to the rapid growth in SA. The high demand for electricity increased the rate in oil domestic consumption for generating electricity and transportation. Figure 26 shows the electricity consumption by user type (Saudi ministry of water and electricity. A historic hint).

4.3 King Abdullah's City for Atomic and Renewable Energy (KACARE)

On 7 April 2010, King Abdullah announced the establishment of a renewable energy city. This motivation for this city came from the rapid growth and development in SA. With the growth, the demand for electricity and desalinated water sky rocked. Therefore, the leader of the Saudian royal family, King Abdullah announced this project to create a green renewable city.

In achieving its purposes a plan outlining the responsibilities of this city without limitation to its terms of reference was established. The first point calls to establish a national atomic and renewable energy policy and set a strategized plan for implementing such policies, bylaws, and regulations. Secondly, the application of specific scientific research programs in this field whether they be independent of the nation of SA, or jointly interested research programs involving other kingdoms. The city will need established organized projects for itself and

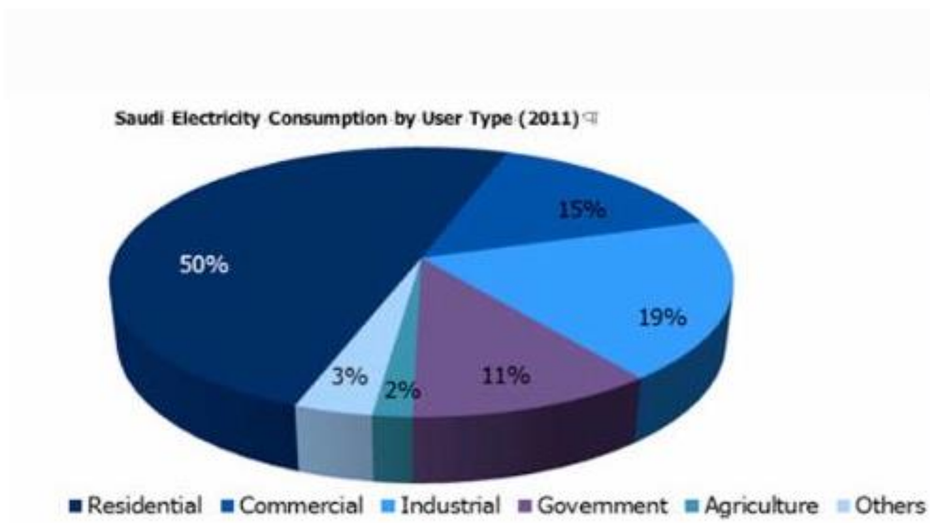

Figure 26. Power consumption by user type.

cooperative work projects with other peer organizations and global research centers. Next, it is of the upmost concern to involve the private business sector to invest in the development research of medical, agricultural, industrial products, and on mining, power generation, desalinated water, and finally the rationalization of water use to preserve natural resources and increase the efficiency of this city. Also scholarship money will be needed to educate people and fund the research for the specific scientific programs. Regulations will need to be issued to protect the people working on and near the city from hazards related to atomic energy radiation. This project will also need training facilities and specialists in the atomic activity and health protection fields.

There needs to be a subcommittee arranged to represent the city in all business dealings with relevant international organizations such as International Atomic Energy Agency. There will be a need for without consideration for research contracts that provide financial assistance, facilities, experts, and other required research materials. These essential entities will need to be readily available to individuals and institutions such as Universities and their authorities to work on the development of this city.

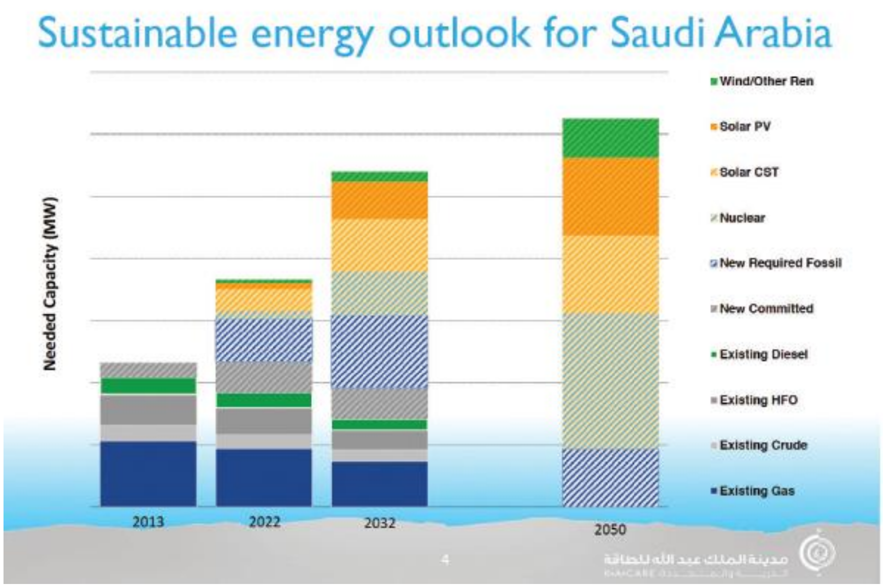

Figure 27. Sustainable energy outlook of SA.

Finally, this city will be a self-sustaining organization that takes responsibility for supervising and controlling all works related to the use of atomic energy and the resulting radioactive rays, and the city shall meet the nation’s obligations in regard to both atomic and other forms of renewable energy. Figure 27 shows outlook for the power in SA for the next three decades including all possible renewable energy sources. The aims of this outlook are increase the power sources in SA and decrease the power dependency on oil (K.A.CARE, 2010)

4.4 SA's Electrical Grid

The electrical grid in SA is not yet considered a smart grid. The smart grid is the ideal type of electrical grid because it delivers electricity from suppliers to consumers using digital technology. The benefits of a grid like this include cost reduction, reliability, and a transparency between the supplier and the consumer. For example, entities such as connectivity, automation, and coordination between suppliers and consumers are increased with a smart grid. Also there has been a proven increase amongst networks that perform local distribution tasks and provide long distance transmissions.

SA is in the process of transitioning from an old model electrical grid to a smart grid. The old traditional grid is about interconnected power transmission systems. This system begins at the power plant. Electricity is generated at the plant and then sent to the first substation. Next the electricity is transferred to many smaller substations. Finally, then the electricity is sent to the consumer through electrical cables and transformers. With the traditional grid, it is difficult and time consuming to isolate the source of a power failure when one occurs. First a technician has to go and locate the source of the power failure and repair it before power can be restored. However, a smart grid allows different areas of the electrical grid to route power to high demand areas in the cases of a power failure. Another benefit of a smart grid is its self-healing nature. A grid can respond to any failure that occurs. It will automatically troubleshoot, compensate for, and heal any found failures. The smart grid does so by using autonomous sensors and controllers that detect and respond to problems in the system. This technology makes it easy to isolate the failed areas and re-route the flow of power.

Since SA made the decision to invest $109B into the development of renewable energy, it has decided it needs a smart grid. First, there is no efficient method in which to incorporate renewable energy sources such as solar, wind, and geothermal on the traditional grid. The smart grid can handle the RES efficiently because of the high management technology system. This system can control the power transmission and distribution systems in the most efficient way. Building a smart grid will connect the abundant RES in SA to power lines. Doing this will conserve oil for economic purposes. It will also allow individual customers to sell their extra generated energy, for example from stored solar, back to the grid. Individuals participating in generating energy will enhance the efficiency of a smart grid by adding energy.

4.5 Solar Energy

In 1980 SA and the US joined forces on a solar energy project, The Solar Village. The aim of this project was to use solar technology to improve the life of people living in small rural agricultural villages. The cost for the project was footed by the Saudi government. They invested $100M in the expansion of solar energy in their nation. The role the US played was to aid in research for this project. This Solar Village was built 45 kilometers North West of the SAn capital, Riyadh. A PV power system was installed in Wadi Haneef atop a step escarpment. The villages that had access to this PV system included Oyaynah, Aljubaylah, and Alhijrah. Prior to this project, these rural areas were isolated villages with no adequate power sources, nor were they connected to the grid. These villages at the time had a combined population of about 4000 people. For the duration of this project, the solar village's installed capacity was 350KW. At the end, the final cost of this project was $18M (Sayigh, 1988).

SA has 12 to 13 hour long days in which there is a predominant amount of sun. Even though solar radiation does not cover the entire nation, certain areas of the country have the potential to generate 2200 thermal KWh /m^2 (Al-Shehri, 2010). However, this mass potential is yet to be exploited because of the availability of oil and the high government subsidies for oil electricity generation.

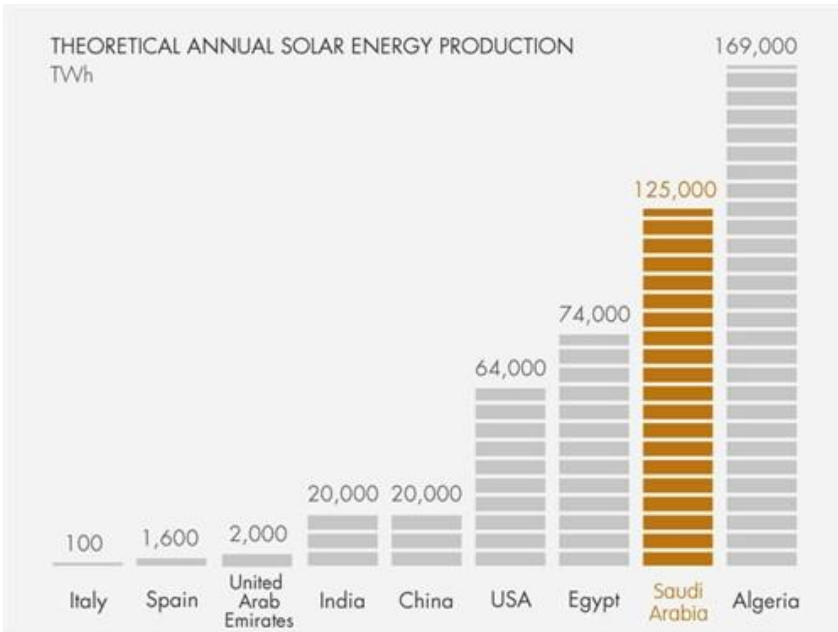

Figure 28. Potential of solar energy in SA.

In 2012, the SA government announced it would invest $109B over the next twenty years in solar energy development. One of the benefits for SA when exploiting RES like solar is economical. In using more solar and less oil, SA will conserve the oil barrels for export to other nations. There is a tremendous potential for solar energy generation in SA. It has close to twice the capacity of any European nation for thermal solar irradiation, with the ability to generate about 2550KWh per square meter annually. With a land area of 2.225MKm^2 this means SA has the potential to generate 125.000TWh annually see figure 28 (K.A.CARE, 2012).

This is more than USA, China, India, and Spain combined. SA’s coordinates are 24.2° N and 43.6° E. This puts SA just north of the equator leaving it with a hot and dry climate. These long sun peak hours and minimal rainfall and the location of SA, make it a very suitable site for the generation of solar energy.

US lies much further north of the equator with Nebraska's coordinates being 40.4° N and 98.7° W. Compared to SA most parts of US experience more rainfall and have shorter days. However, there are some parts of California that are desert and have a more applicable climate for solar energy exploitation, but the country as a whole just does not have the potential that SA does to exploit the sun's thermal energy, due to the different type of climate. Figure 29 shows the annual global solar radiation in SA.

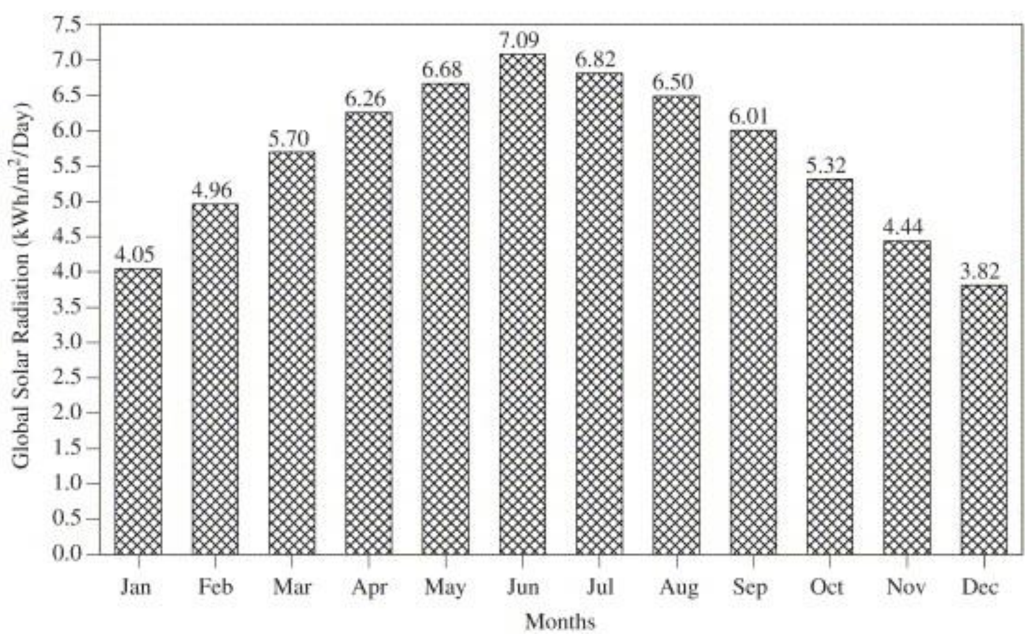

Figure 29. Seasonal variation of global solar radiation over SA.

SA proves to be a nation with a tremendous potential to generate solar energy; sadly, SA has 3MW installed capacity. One of the reasons for the lack of solar energy is oil. Oil is SA's number one export, and it is the leading exporter of oil in the world. Because of this, the government and private sector are very focused on this resource. There is no real planning within different departments of the government, and there is a high government subsidy for electricity generated by oil. In the next two decades, SA has goal to have an installed capacity 41GW of solar energy.

4.6 Wind Energy

Wind energy development in SA began in 1986. It started with the creation of a wind atlas. A wind atlas keeps information on wind speed and wind direction for any given region. This atlas is comprised of frequency distributions and maps. SA's wind atlas is made up of data from twenty locations and includes information on the wind speed in those areas. There are two known vastly windy regions in SA, the Red Sea Coast in the west and the Arabian Gulf in the east. The average wind speed in these areas annually is 17Km per hour (Ansari, Madni, . Bakhsh, 1986)

In 2003 The Center of Engineering Research at King Fahd University for Petroleum and Minerals published a study on wind power cost assessment for twenty locations in SA. Three different wind electrical conversion systems were studied in order to determine the wind power cost per kilowatt per hour. The study was done on three different sites, one in the east on Arabian Gulf Coast, one in the central area, and one in the west along the Red Sea Coastal area. The data was collected for approximately thirty years. The study ran from 1970 to 1982. The average speed per hour was studied in order to calculate the payback and better understand the benefits for utilizing wind power for these locations. Three wind machines were used in this study, one with a capacity 2.5MW, one with 1.3MW, and one with 600KW. For over 50% of the time, in four cities on the western coastal area: Al-Wajh, Yanbo, Jeddah, and Gizan and one city on the eastern coastal, Dhahran, wind was available above the desired wind speed.

In addition, inland locations were studied as well. In areas such as Riyadh, Medina, Badana, Rafha, Quasumah, Turaif, and Taif the wind maintained a speed of approximately 45%

annually. In areas such as Al-Jouf, Gassim, Nejran, Hail, and Bisha the wind maintained a speed of approximately 35%. The purpose of this study was to determine the US dollar cost per kilowatt of wind energy. This study found that using machines with 2.5MW would average a minimum cost of 2 to 7 cents per KW/h, a machine with 1.3MW would average a minimum cost of 3 to 8 cents per KW/h, and a machine with 600KW would average a minimum cost of 4 to 12 cents per KW/h (Rehman, Halwani, Mohandes, 2003).

For 33 months beginning in 2006, there was a wind energy study conducted in Juaymah, an eastern region of SA, lying at 26° N and 49° E . This area is on sea level; moreover, these off shore areas are ideal locations for wind generation because there is applicable space to construct wind farms. In addition, the off shore regions are more predictable and have less turbulence. For this study, the data was collected by using a forty meter tall wind tower. In addition, the data was collected at four different heights: ten, twenty, thirty, and forty meters. The recorded data was comprised of wind speeds, wind direction, air temperature, relative humidity, service station pressure, and global solar irradiation. The yearly average wind speed was 4.1M/s at ten meters, 4.8M/s at twenty meters, 5.3M/s at thirty meters, and 5.7M/s at forty meters.

In addition, the predominant wind direction proved to be NNW and NW. In addition, the approximate density values of wind power at ten meters was 85.5W/m^2, at 20 meters it was 119W/m^2, at thirty meter it was 154.2W/m^2 and at forty meters it was 180W/m^2. The research was a cooperative effort conducted by both, The King Fahd University for Petroleum and Minerals in SA, and The University of Pretoria from South Africa. The main goal of this study was to gain an assessment of wind power, wind shear exponent, air turbulence, intensity, plant capacity factor, effect of hub, height on energy yield and energy yield in general ((Alam , Mahbub, Rehman, Meyer, Al-Hadhrami, 2011).

SA plans to generate 9GW of wind energy by 2050. Ideally this will reduce the CO_2 admissions in SA and free up oil for exporting. For now K.A.CARE is working on the development of a new wind atlas. This new atlas will be based off of all the new research and studies, and will also cover a much broader land area. The new atlas will also include data on solar, geothermal, and waste derived energy. K.A.CARE will work alongside the Unites States National Renewable Energy Laboratory (NREL) and The Battelle Memorial Institute to develop this new broader atlas.

4.7 Geothermal

There is a strong potential for geothermal energy in SA. Throughout SA there are ten hot springs from which geothermal energy can be exploited. These hot springs vary in temperature from 50C° to 100C° and have different flow rates. These springs are all located in the southern region of SA. Six of them are in Gizan, Ain Khulab, Ain Khulab Quwa. Ain ad Damad, Ain al Wagrah, and Ain al Wagrah Dam. The other four are located in Al-Lith area, Ain al Harra, Ain Jumah, Ain Markub, and Ain ad Darakah. In addition there are other geologically active areas such as harrats, volcanic lava fields, which also make SA rich with the potential for geothermal energy. There are three main harrats in SA, Khaybar, Kishb, and Rahat. These harrats are located in the western part of SA. These harrats as well as smaller ones can be studied for geothermal energy exploitation.

Currently in SA there is no installed capacity of geothermal energy but studies on geothermal date back to 1980. In 2005, Shafiqur Rehman and Ali Shash from The Research Institute at The King Fahad University of Petroleum and Minerals examined previous studies dome on geothermal energy in SA. They found that Khaybar and Rahat had the highest temperature flow of all areas in SA. The Rahat lava field covers an area of $20Km^2$ and has 644 scoria cones, 36 shield volcanoes, and twenty four domes. For both harrats they found the average temperature was 730C°-900C°. Below both of these harrats, in the Earth’s crust, there exist extremely high temperatures and molten materials that can be used to generate electricity (Rehman, Shash , 2005).

Another analysis was conducted to support Rehman and Shash’s conclusions. This studied was conducted by H.M. Taleb from The School of Architecture at the University of Sheffield in the United Kingdom . He included more harrats in his analysis. He used harrats from the North, Harrat ash Shamah, and Harrat Hutaymah in central SA. After examining these harrats, Taleb came up with similar numbers as his contemporaries.

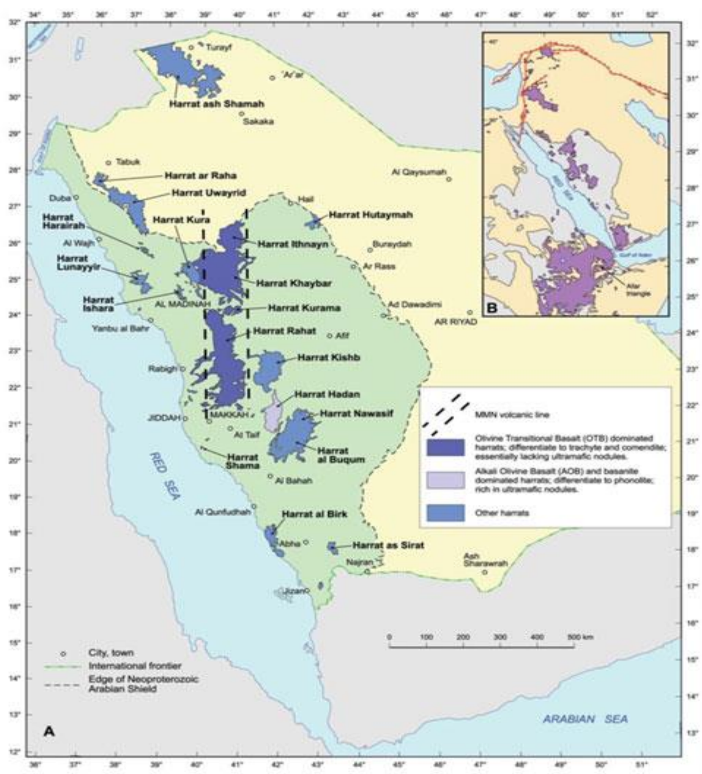

Figure 30. Harrats map in SA.

Taleb asserts some recommendations on how to develop the use of geothermal energy in SA: the existence and feasibility of geothermal energy in SA must be considered, Initial pilot projects must be implanted to examine whether there is a workable system in existence, there must be a mutual plan devised between geothermal stakeholders, decision makers, investors, and the private sector. Scientist and academics must also get on board to aid the development of geothermal energy in SA. It will be essential to use educational companies and the media to transform these plans into commercial projects. SA needs to involve other advanced nations to aid in the development of its geothermal energy plans (Taleb, 2009).

There is need to train and qualify people in this clean geothermal energy field to raise awareness and generate a skilled workforce in this area. K.A.CARE intends to work with the geothermal stockholders to raise the economic viability of geothermal energy. The target installed capacity for geothermal energy is 1GW by 2032.

4.8 Biomass

Currently, there are no actual biomass plants running in SA, but K.A.CARE announced that they are looking to generate 3GW of waste-to-energy by 2030. The majority of the future potential for generating energy with biomass in SA will come from landfills that contain solid waste. By exploiting solid waste for biomass energy, these landfills will be reduced, which will in turn reduce the environmental pollution in SA.

CHAPTER 5

Small Scale PV System Simulation Using HOMER Software

5.1 Introduction

In SA, currently there are many incentives for renewable energy sources RES as promoted by K.A.CARE. PV is the most popular renewable energy that currently is been studied in SA. There are many locations there that have higher solar radiation, which leads to high potential for solar PV energy. The annual climate of SA in general is dry and has low rainfall. The sun is shining most of the year; there are also long days ranging from 9 to 13 hours. The geographic nature of the country is mostly flat desert except of some locations south and west where Al-Sarawat Chain Mountains lay from Makah region all the way down to Yemen. SA's PV energy potential is twice that of the potential in Europe.

Table 7

Annual solar radiation on Dhahran city.

Month	(kWh/m²/d)
January	5.174
February	5.449
March	6.275
April	6.501
May	6.816
June	6.874
July	6.527
August	6.326
September	6.666
October	6.305
November	5.569
December	5.050

The eastern region of is flat and on the sea level with high sun radiation. One of the high PV energy locations there is Dhahran city, which has a latitude of 17.6627° North, and a longitude of 43.5059° East on the world map. Due to its geographical location, it has a higher solar radiation potential with an average of 6.1kWh/m²/d as shown in table 7.

The objective of this study is to use HOMER to simulate the dual-tariff concept system design for solar PV plants based on a real structure in Dhahran, SA. HOMER is a software program that simulates the financial investment and gain that comes from implementing a PV system in any given area. HOMER also works with conventional power systems and other hybrid systems, but for the purpose of this study, it will be illuminated insofar as it works on a PV system. HOMER will be used to design an entire solar system by collecting solar radiation data from other websites such as: nrel.gov and nasa.gov, and by entering the coordinates of the desired location. Then, the results will be examined to analyze the cost-benefit of the overall system which requires output supplies of 15kWh. If this system if implemented, it will work as a dual-tariff. In addition, it can work as a stand-alone apart from a grid system, where the solar PV will supply the load all day long, while the local energy supplier, Saudi Electrical Company (SECO) supplies the energy in case of a system failure.

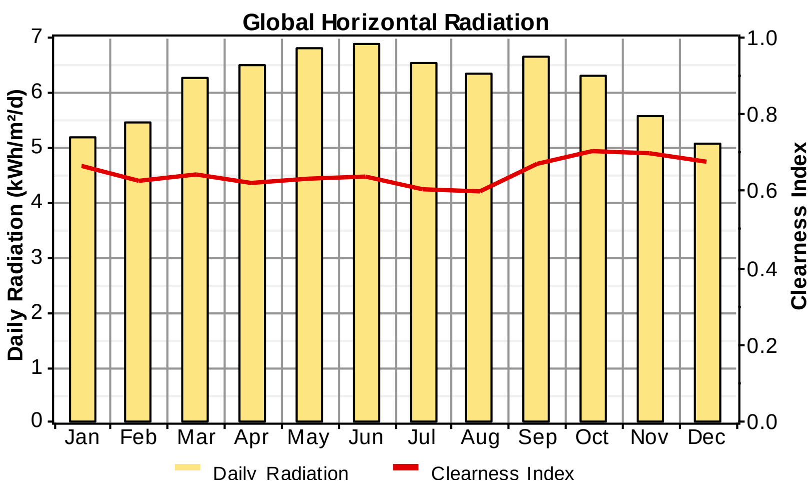

Figure 31. Annual solar radiation tabulation for Dhahran.

The tabulated data in table 7 is very much critical in calculating the amount of solar energy or in specific terms Solar Irradiation, which will be obtained throughout the whole year.

Figure 31 shows the clearance index which is the proportion of the extraterrestrial solar radiation that makes it through to the surface average of 6.4 for the most months of the year.
The number of Peak Sun Hours (PSH) is the solar power intensity used based on Global Solar Radiation at sea level (G0) = 1 kWm². This figure is used during this system's designing stage as a best practice figure, even though it can be higher than 1kW/m². One of the main objectives in developing the solar PV system is purely on the cost effective feed-in tariff. This includes an effort to offset the electricity consumption during the day for the customer, by using such initiatives as Co-generation and Dual-tariff Systems (Ibrahim, Othman, Damanhuri, Radzali, Husain, 2010).

In co-generation systems, localized generators are used to offset peak demand hours resulting in substantial economical reductions on utility bills. However, co-generation gives some negative effects such as producing noise to the surrounding area. Whereas, with the dual-tariff systems, the utility encourages electricity usage during night-time with low tariff rates between 7 pm – 6 am. It is a common practice that has been developed in cold-weather countries such as Britain. Storage heaters have been implemented and widely used in the countries. Thus, with the implementation of the dual-tariff concept, electricity bills will be reduced by a large amount due to supplying the on-peak demand hours from the solar PV plant.

5.2 Methodology

5.2.1 The system structure. The PV system will be installed as a standalone system. The location for such system can be located on the roof of a building or a typical house that operates for 24 hours using a load of >10kWh/day. The supply system is modified to suit a dual-metering, to monitor actual usage.

In case of a system failure, the local energy supplier, SECO will supply the energy. The system is provided with battery storage backup to regulate deficiencies in unreliable solar energy. During the day time, the solar energy collected by the PV will be used to operate the full system connected to the house and charge the battery bank. Figure 32below illustrates the dual-tariff solar PV system in the system.

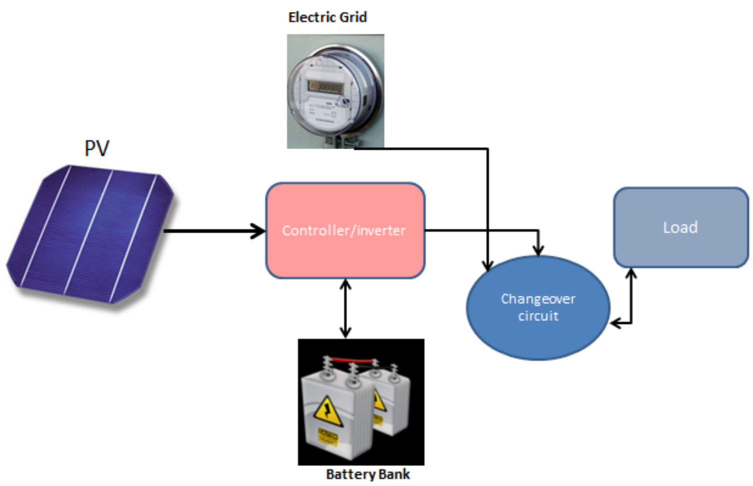

Figure 32. Dual-tariff system employing the use of PV Source and SCECO grid.

The change over the circuit is used to connect the load to the PV system during the day and change connection to the grid if needed. The extra energy can be fed directly to the grid using two ways net-metering that will be supplied by the local power company. Figure 3 shows more details for net-metering which give consumers the ability to sell back their extra power by feeding directly to the grid and get credit on their utility bill. This new metering system is available in many countries all over the world. However, Net-metering regulation is still not yet implemented in SA, but for future plans with SA's smart grid and RES, net-metering technology will be one of the typical emerging technologies to increase the consumers contributions to the grid by selling back their extra power from their own RES's.

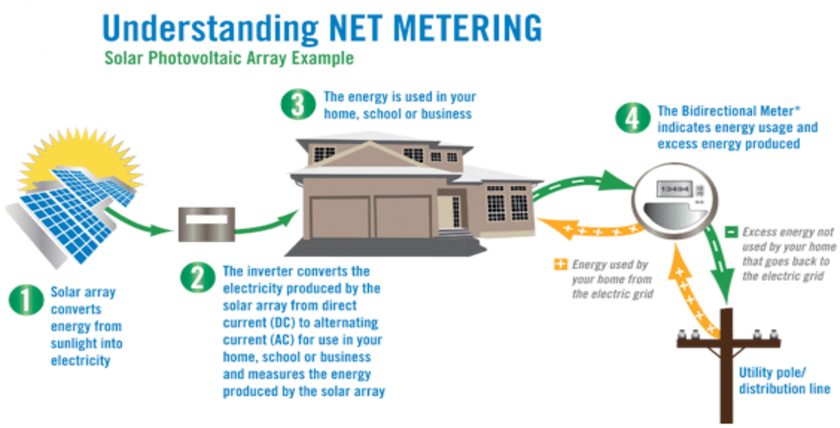

Figure 33. Net-Metering.

5.2.2 Economical study. The economic study is implemented in order to investigate the total cost for solar PV plant installation, the operation and maintenance cost, and the payback time. By using HOMER software provided by National Renewable Energy laboratory (NREL), the simulation on the economic study is done. The solar energy data and the estimated cost of each component in the solar PV plant are used as inputs to the software. The hourly load for the PV system is measured and used as an AC load to the software. The study data was based on the month of July in which had the highest temperature and the highest power demand for the year.

5.2.3 Finance. The high cost of the system's installation can be daunting for low and medium income people. There are many government agencies that can finance the project like the Saudi Credit and Saving Bank (SCCSB) and Real Estate Development Fund (REDF). These agencies are nonprofit organizations supporting the sustainable development of SA. In addition by using renewable PV solar energy, SA can conserve its oil for export and profit. The government can then set aside a portion of these profits to cover the costs of installing PV systems on people's homes. K.A.CARE can govern the regulation of the financing and implementation of solar systems for private and business sectors. On the other hand, private business sectors can contribute with law interest financing programs under the regulation of the system funds.

5.3 Result and Discussion

5.3.1 Energy analysis. To simulate the energy yield and cost analysis of the solar PV plant, the hourly load from the PV system is measured and computed. Table 8 tabulates the electrical appliances that can be used in a normal small house using the PV system as a utility with their time of usage during day and night. The system supplies the solar PV energy for 24 hours. The computed annual average load for the system is depicted in figure 4.

Table 8

List of Electrical Appliances in the house.

Equipment	W	Qty	Hours/day	KW/d/yr
Air condition 3.5ton	6500	1	12	78
Fluorescent Lamp	20	12	8	1.9
LCD-TV 45Inch	147	1	8	1.176
Ref. 16 cu. ft.	600	1	12	7.2
Vacuum cleaner	630	1	1	0.63
Washing machine	512	1	1	0.512
Water heater	2500	1	3	7.5
Hand iron	1100	1	1	1.1
Coffee maker	1000	1	1	1
Microwave oven	1400	1	1	1.4
Computer	240	1	5	1.2
Ceiling fan	90	1	3	0.27
			Total	101.9

The electrical appliance in Table 8 is selected based on the house requirements. Air conditioning is used throughout the day in order to regulate the house temperature. Also, other appliances, such as a microwave or a vacuum cleaner, are used based on the daily life's demand of the people living in the house. The daily load during July can be seen in Fig 5.34 which shows that air conditioning system carries the major kWh usage because of the hot climate in SA during the summer months.

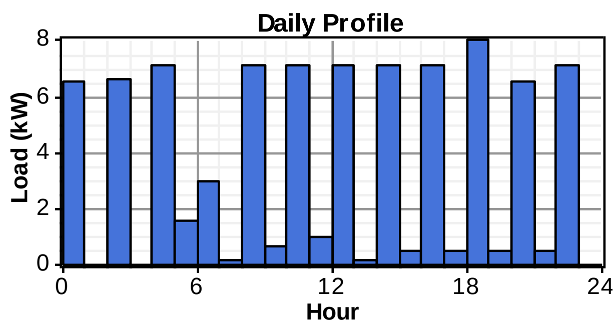

Figure 34. The appliances daily profile.

Figure 35 shows the average load that is required for the house annually. On a monthly basis the power consumption runs at almost the same rate, but the air conditioning system operation hours will vary during winter time with the exception of all electrical homes that rely on electricity for heating their homes in the winter.

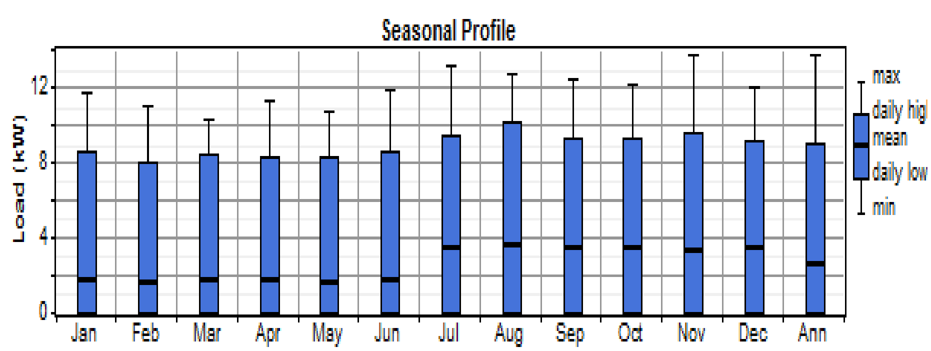

Figure 35. The system annual average load.

By further analyzing from the load demand of the house using HOMER, the PV system architecture is proposed as mentioned in Table 9.

Table 9

Proposed System Architecture.

Component	Description
PV Array	15KW
Battery	48
Inverter	15KW
Rectifier	15KW
Grid	N/A

Based on the proposed system architecture in Table 5.9, a 15kW PV array is combined together with a system voltage (SV) of 48V in order to accommodate the sufficient load in the house. The batteries used during this design process are a Trojan L16P type, which each have 6V and a capacity of 360 Ah. In addition, each string is comprised of eight batteries connected in parallel strings of six, and 48 batteries are used in this study. Also, the converter used in this study is a 15 kW inverter system, used to convert from DC to AC supply.

5.3.2 Economical study. In this study, the estimated cost for the solar PV dual-tariff system implementation is predicted using HOMER. The estimated cost included the capital cost, replacement cost, operation and maintenance cost and salvages cost (value at the end of the project lifetime) for each component of the system as tabulated in Table 10.

Table 10

Detail Cost of the Solar PV Dual-Tariff System.

Component	Capital ($)	Replace ($)	O&M ($)	Salvage ($)	Total ($)
PV	11,200	3,492	0	-1,957	12,735
Grid	0	0	-2,376	0	-2,376
Trojan L16P	7,200	5,917	0	-792	12,325
Converter	4,000	1,669	0	-311	5,358
System	22,400	11,079	-2,376	-3,060	28,043

This PV Dual-Tariff System has a total capital cost of $22,400, a total replacement cost of $11,079, a total operation cost and maintenance cost of -$2,376, and salvages cost are -$3,060 respectively. From the estimated cost summary, it is expected that this system will have a payback time frame of less than 25 years as depicted in figures 36 and 37.

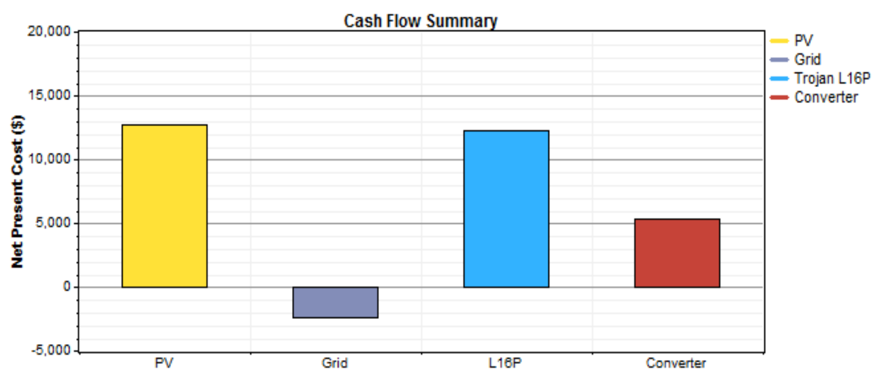

Figure 36. Capital cost for all component.

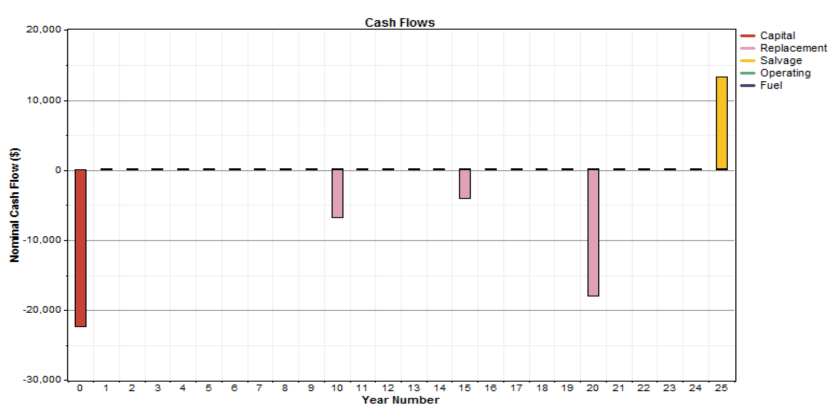

Figure 37. System cash flow.

5.3.3 Grid credit. As table 5 shows the annual energy purchased by the grid is 16.844KW/h. The system owner can deduct this amount from the PV system's annual cost by selling back to the smart grid. Using the PV system this way will enhance the smart grid and reduce the power loses. This enhancement and reduction takes place because the system owner is contributing energy to the smart grid and not relying on it for energy consumption. In turn, this also reduces fossil fuel burning and CO_2 emission because clean green energy is being used and sold back to the smart grid.

Table 11

Grid Rate.

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	1,197	1,940	-743	12	-37	0
Feb	1,020	1,715	-695	11	-35	0
Mar	1,185	2,032	-847	10	-42	0
Apr	1,128	1,874	-746	11	-37	0
May	1,119	1,912	-793	11	-40	0
Jun	1,139	1,797	-658	12	-33	0
Jul	1,674	1,059	615	13	8	0
Aug	1,854	1,062	792	13	10	0
Sep	1,617	1,230	387	12	5	0
Oct	1,634	1,343	291	12	4	0
Nov	1,561	1,233	328	14	4	0
Dec	1,716	1,185	531	12	7	0
Annual	16,844	18,383	-1,539	14	-186	0

5.4 Study Conclusion.

The system design and cost analysis of the dual-tariff solar PV system has been simulated and forecasted using HOMER with an energy peak demand of 14kWh/m²/d. These results depict that the design of the dual-tariff system can be accomplished for a total capital installation cost of $22,400, replacement costs equal $11,079, operation and maintenance costs equal -$2,376, and salvage costs equal -$3,060 respectively see table 11. It is expected that the system will give a payback amount to the system owner in less than 25 years. Thus, the implementation of a dual-tariff concept will save the utilization of energy from the national grid and reduce a large amount of the system owner's electrical bills. In addition, the potential of back sale to the grid is high, which means with the adoption of net-metering technology the system can credit the user and reduce the payback time. This system is ideal for out of grid rural areas.

There are many areas that can benefits from a dual-tariff system. Locations such as: government border centers, telecommunication companies that operate abundant tower systems, and SA's abundant small villages. The system can be modified to meet the user's demand, so the components can be reduced or increased according to the consumer peak demand. HOMER software has all the components needed to simulate more systems with more components.

5.5 Small Scale PV (SSPV) Systems versus Large Scale PV (LSPV) Systems.

SA is still at the beginning of the road with PV systems. They have targeted to produce 41GW of PV system in the next 2 decades. Most of the available projects now are small scale projects like the one in King Abdullah Petroleum Studies and Research Center (KAPSARC) in Riyadh city and the other project that under construction in Farasan Island in the southern region. Small residential scale PV systems are more efficient than commercial and large scale PV systems for many reasons. For example, they take up less area, the power losses are on a much smaller scale, and the climate is more guaranteed for a smaller system in a smaller area.

5.5.1 Required area. According to Mississippi Solar LLC, the physical size of a solar array depends on the output desired. Solar panels commonly sold today measure approximately 65” x 39,” weigh about 45 lbs., and are rated at between 200 and 230 watts each. A solar array rated at 1 kW would require 5 panels and cover approximately an area of 90 square feet. Under ideal conditions (i.e. proper orientation, no shading) this 1 kW array would produce, on average, about 4 kWh of electricity daily (a 100 watt light-bulb will consume 4 kWh of electricity in 40 hours). That’s about 120 kWh a month on average. Using these numbers as a guide, a 5 kW array would on average produce about 600 kWh of electricity a month and would take up about 450 square feet. Small scale PV systems don’t require large areas.

Table 12

Average home appliances in SA.

Appliance	Wh/d
AC	4000
Refrigerator	600
TV	147
Washer/dryer	700
Computer	120
Monitor	150
Water heater	600
Lights	700
Vacuum cleaner	500
Iron	1200
Total	8700

The panels can be installed above the house roof, parking lot, or in the backyard. In SA the average house area is $1600ft^2$. A small scale PV system of 17 KW will not require more than $1600ft^2$ if 5KW per 450 ft^2 is used (Mississippi Solar LLC). Most of the house roofs in SA are flat, made of solid concrete, and not regularly used. SA is a dry country that has no forest, so nothing can obscures the sun except for clouds. Table 12 shows the average house power usage in SA. As per table 12 the total of power consumption is about 8.7KW if they all used altogether.

5.5.2 Transmission losses. Commercial and industrial scales require long transmission lines which raise the cost and power loses. Current loses can be calculated by the following equation

$$P_{lose=}\ I^{2}R$$

In his book (Energy from the Desert) 2009, Keiichi Komoto had calculated the loss current in a very large PV system. He used a 5 steps procedure to calculate the current loss in the system.

The First step calculates the daily irradiation curve for 12 months using the Berlage mode. The second step was using the following equation to make the daily day curve It was off course taken into consideration the radiation changing per day be it a sunny day or a cloudy day, and the current losses of each cable.

Table 13

Losses ratio in six deserts with 30° tilt angle structure.

Desert	Corrector loss (GWh/y)	Transmission Loss (GWh/y)	Power generation (GWh/y)	Loss ratio %
Sahara (Mauritania)	5.9	7.5	194	8.2
Sahara (Morocco)	3.8	4.6	166	6.3
Negev (Israel)	3.7	4.4	156	6.4
Thar (India)	4.4	5.4	170	7.1
Sonoran (Mexico)	3.9	4.6	162	6.5
Great Sandy (Australia)	4.0	5.2	175	6.5
Gobi (China)	3.4	3.9	160	5.8

In his study he compares different locations worldwide: The Sahara desert in Mauritania and Morocco, The Negev desert in Israel, The Thar Desert in India, The Sonoran desert in

Mexico, The Great Sandy desert in Australia and The Gobi desert in China. The assumption of equipment in the study was 110kV/6.6kV transformers, SVC (Static Var Compensator) with 99% efficiency, and a Power factor of 90% (Masakazu, Karuhiko, Keiichi, Tetsuo , Kurokawa, 2005). In this study it is concluded that The Sahara generated the most power with 194GW. However, it also had the biggest loss, 8.2%, which is about 15.9GWh/y. The Gobi desert, which had the lowest generation, had the lowest loss 5.8%, which is about 9.3GWh/d. This information is depicted in table 13.

Table 14

Monthly Sun radiation in SA and West Sahara.

Month	SA (Average) (KWh/d)	West Sahara (Average) (KWh/d)
January	4.435	4.606
February	5.265	5.318
March	6.158	6.323
April	6.803	7.184
May	7.190	7.633
June	7.658	7.188
July	7.367	6.917
August	7.005	6.533
September	6.606	6.191
October	5.625	5.633
November	4.566	4.762
December	4.186	4.225

In comparing The SA Desert to the result of the Sahara desert in the study, they almost have the same sun radiation and almost the same climate which is dry and with low rainfall. Table 14 shows the annual sun radiation in The West Sahara Desert and The SA Desert. The average annual sun radiation is 6.07% in SA and 5.99 in The Western Sahara Desert. The annual average sun radiation in SA is more than the Sahara desert which leads one to the conclusion that the power loss will be equal or more than The West Sahara Desert. Despite the low capacity of the SSPV systems, Solar PV systems may result in reduced transmission and distribution losses. This is due to the source of production which would be much closer to the final point of use compared to the LSPV systems.

5.5.3 Climate affects. Large systems located in one large area of the same geographic land will be affected by the present weather at the same time. In a country like SA which has many geographic areas containing mountains, desert and canyons, the weather can be different from one area to another. Table 15 compares four cities in SA in different regions, Tabuk in the North West, Abha to the South, Sulayel in the South Central, and Dhahran to the East.

Table 15

Average cloudy day and rainfall in different city in SA.

	City and Total rain fall (mm)			
Month	Tabuk	Abha	Sulayel	Dhahran
January	8.5	15.3	0	25.7
February	1	0	0	0
March	0<x<1	0<x<1	0	0
April	0	17.8	0	0
May	0	34.4	0	0<x<1
June	0	7.5	0	4.7
July	0	3.4	0	0
August	0	4	0	0
September	0	0	0	0
October	0	4	0	0<x<1
November	1.5	21.1	0<x<1	0<x<1
December	0<x<1	0<x<1	0	1.1

As shown in Table 15, the average rainfall is different from one city to another, Sulayel has the lowest rainfall and Abha has the highest. The efficiency will be affected when the sun hides by the clouds. For example in Abha, the system production will be the lowest of the different cities. The small scales PV systems can be located anywhere and spread all over the country. In addition, it can feed the smart grid which can manage and distribute the load according to the demand.

In conclusion, the small scale PV systems require a small area and can be placed on unusable places like house roofs which will not affect the land or any animal habitats. In addition, when the power supply is located closer to the end, the power losses will be much lower than long distance transmission. Constant similar weather patterns will affect LSPV systems that are located in one area. SSPV systems are far less susceptible to this caveat because they are spread out all over the country. Despite the KW cost of SSPV system installation, the SSPV systems can be more flexible and reliable more than the LSPV systems for the reasons mentioned above. They can be connected to the smart grid as small DR systems, feeding their load from anywhere to the electrical grid. On the aesthetic matter of solar panels, SSPV systems will give people something to consider when designing their homes and will increase the awareness of power importance in their lives.

CHAPTER 6

Future works and Conclusion

Many researches had been conducted in RES area and still more to come in SA. Fossil fuels are a finite resource and therefore, something that is dangerous for people to rely on. In addition, fossil fuels are harming the plant with the emission of CO_2 gases that come along with them. The greenhouse effect is a very really caveat that people ought to be concerned with. It is a fact renewable energy sources are the way of the future. RES are clean green resources that will not have a negative impact on the environment. Many western nations such as The United States, Germany, and China have already made some significant progress with many forms of RES. The two main RES which have had the most development are solar (PV) and wind energy. However, progress is also being made with geothermal, biomass, hydro-electric, and fuel cells.

The development of smart grids has also been a major progression in the future of energy. It has made energy more efficient and reliable for the consumer. Power failures are no longer as big of a problem as they used to be, and with net metering, consumers that choose to use RES can sell their energy back into the grid for a credit. The smart grid is also important for RES because it allows for all of them to be connected. This means that if one RES is out of commission, that another one can compensate for it.

SA future as a growing country at the beginning stages of renewable energy more research is needed for RES. There is so much potential in this country for RES because of its climate and location. It is also important for their economic. SA is the world's leading producer of oil. If it can convert its people to using RES, then the oil can be saved for export and profit. Currently the most researched RES in SA are solar and Wind. Also, SA has yet to get a smart grid. A smart grid will be important for this nation's future development of RES.

Nations such as the United States, China, and Germany who are used to importing fossil fuels are currently the world leaders in the development of smart grids and RES. However, SA has begun using some RES but on a much lesser scale. For years these industrialized nations have developed the use of smart grids and RES. SA however, is still on the old electrical grid. In SA There is a good funding for RES though King of SA, King Abdullah has created a city, K.A.CARE for the progression of RES. Because of this city and its funding, many studies on the potential of RES in SA have been conducted. However, solar energy is still the only RES to have an installed capacity.

HOMER software program was developed by The National Renewable Energy Laboratory (NREL). This software allows designing RES systems simulations. System simulations of PV model, depicts how the city of Dhahran can have smaller PV systems. It shows the economic efficiency for using a duel-tariff system. We also give evidence in the thesis how useful the small PV systems can be as oppose to the larger scale system that must deal with location issues.

The strength and usefulness of a small scale dual-tariff system has been depicted through a HOMER simulation for the city of Dhahran, SA. If these nations continue to use technology to develop and deploy RES systems it will improve the human condition. It will keep the planet healthy for many generations to come because it will cease the emission of CO_2 greenhouse gases. In addition, it will guarantee energy for the future with no threat of running out of a finite fossil fuel resources.

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