Selecting Renewable Energy Sources for Small Islands Using Analytical Hierarchy Process (AHP)

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ABSTRACT

In this modern era, energy became a necessity product in order to have a good quality in life, human development and growth in economy. However, most of the countries' energy sectors depend on the importation of primary energy products from other countries which reduces the growth rate and the quality of life of the home country. Moreover, this dependency jeopardizes these factors. Small island countries, which are not integrated to main land, have some restrictions in their economies because of the limited primary energy resources and importation payments. Without any importation, those islands' economies cannot sustain. However, they can find some alternative resources in order to reduce the paying money to the host countries and they can keep money inside of the country which can cause an increase in life standards for the residents. This dependence on the imported primary energy products is highly revealed to some changes in political and economic issues depending on the fluctuations in the price level. Therefore, the volatilities in fossil fuels prices and the difficulties for foreseen their prices results the risks for the consumers and suppliers. Depending on this issue, renewable energies become crucial alternative energies in order to provide clean and sustainable energy, clean environment and to protect the economy. Accordingly, the priorities of the renewable energies are appraised in this study to find out best alternative renewable energy resource for six small islands' energy sector. AHP model is selected as a methodology for this study which gives the flexibility for the survey needed researches. The hierarchical model for the study consists of four stages which can be listed as goal, criteria, sub-criteria and the alternatives. Small island countries potentials are examined depending on the five main criteria and thirteen sub-criteria by using the AHP model in order to see the best alternative that can contribute its energy sector more than the traditional production and the other kinds of renewables. In parallel with this fact, Costs, Technical issues, Social issues, Locations and Environmental issues are evaluated as the main criteria. Moreover, thirteen sub-criteria are presented for reaching this goal and analyze has been made for Malta, Cyprus, Cuba, Jamaica, Dominican Republic and Singapore separately.

While the main criteria are ranked among each other, mostly the environmental factor has become the most crucial one and followed by the cost, technical, location, and social issues. The rankings in terms of the numbers can be represented as 0.378 (environmental), 0.266 (social), 0.18 (location), 0.115(technical) and 0.061(cost). Therefore; for all islands, Solar Energy is founded as the best potential in order to invest and reach goal. Furthermore, it is purposed that depending on the results and the priority of the renewable energy, the decision makers can benefit from this study in order to develop long-run policy for economic issues with respect to energy sector and create a roadmap for the energy efficiency policy for the country.

Keywords: Renewable energy, sustainable development, AHP, Analytic Hierarchy Process, Small island countries

ÖZ

Modern Çağda, enerji yaşam kalitesi, ekonomik büyüme ve insan gelişim için zorunlu hale gelmiştir. Fakat çoğu ülkelerin enerji sektörünün diğer ülkelerden yapılan birincil enerji ithalatına bağlı olması, ülkedeki ekonomik büyüme oranını ve yaşam kalitesini azaltmaktadır. Ana karaya entegre olmayan küçük ada ülkelerinin enerji ithal eder durumda oluşu onların ekonomik büyümesinin ve ithalat ödemelerinin önünde bazı kısıtlamalara sebep olmaktadır. Herhangi bir enerji ithalatı olmadan bu adaların ekonomik sürdürülebilirliği imkânsız hale gelmektedir. Ancak bazı alternatifler bularak dış ödemelere azaltmak ve ülke içerisinde parayı tutmak ülkedeki yaşam kalitesi artırımına neden olabilir. Bu ülkelerin enerji sektörleri genelde dış ülkelerde yapılan fosil yakıtlarının ithaline bağlıdır. Birincil enerji ürünleri üzerine olan bu bağımlılık fiyat seviyelerindeki yüksek dalgalanmalara sebep olup bazı siyasi ve ekonomik konularda değişikliklere sebebiyet verebilir. Bu konuya bağlı olarak, bu çalışmada, enerji sektörü için alternatife yenilenebilir enerji kaynakları değerlendirilmiş ve en iyi yenilenebilir enerji kaynağını bulmak amacıyla öncelikleri belirlenmiştir. Bu çalışma için, anket gerekli araştırmalar için esneklik gösteren, yöntem olarak Analitik Hiyerarşi Süreci seçilmiştir. Buna bağlı olarak, yapılan bu çalışma için AHS modelinin hiyerarşik modeli amaç, kıstaslar, alt kıstaslar ve alternatifler olarak dört aşama şeklinde belirlenmiştir. Küçük ada ülkeleri potansiyelleri arasından enerji sektörüne daha çok katkı sağlayabilecek olan en iyi alternatifi seçmek için AHS kullanılanılmış ve beş ana ve on üç alt kıstasa bağlı olarak potansiyeller değerlendirilmiştir. Bu esasa bağlı olarak, maliyetler, teknik konular, sosyal konular mekân ve çevre konuları ana kıstaslar olarak değerlendirilmiştir. Dahası, bu hedefe ulaşmak için onüç alt kıstas kullanılarak Malta, Kıbrıs, Küba, Jamaika, Dominik Cumhuriyeti ve Singapur için ayrı ayrı analiz edilmiştir.

Ana kıstaslar birbirleri arasında değerlendirildiğinde, en öncelikli olarak çevresel konular gelmiştir ve önem sırası sosyal, mekan, teknik ve maliyet konuları olarak sıralanmıştır. Sayısal olarak değerlendirildiğinde, 0,378 olarak çevre birinci sırada gelmekte 0,266 ile sosyal, 0,18 ile mekân, 0,115 ile teknik ve 0,061 ile maliyet önem sırası taşımaktadır. Bunun yanında, güneş enerjisi tüm ada ülkelerinde amaca ulaşmak için en uygun yatırım potansiyeli olarak seçilmiştir. Böylelikle, bu çalışmanın, sonuçları ve ve elde edilen önem dereceleri ışığında, karar vericiler için bu çalışma, uzun dönemli enerji sektörüne bağlı ekonomik politikalar için kullanılabilir kaynak olması ve enerji verimliliği için yol haritası oluşturabilir bir araştırma olması amaçlanmıştır.

Anahtar Kelimeler: Yenilenebilir Enerji, sürdürülebilir kalkınma, AHS, Analitik hiyerarşi süreci, Küçük Ada Ülkeleri

To my mom, Nevgül EMİR, unique mother and woman,
and my dad, Hasan EMİR, my best teacher

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MW	Megawatt
kWh	Kilowatt hour
PV	Photovoltaic
IEA	International Energy Agency
CO2	Carbon dioxide
OECD	Organisation for Economic Co-operation and Development
BP	British Petroleum
NREL	National Renewable Energy Laboratory
REN21	Renewable Energy Policy Network for the 21st century
PV	Photovoltaic
GWh	Giga watt per hour
CSP	Concentrating Solar Power Plants
EWEA	European Wind Energy Association
IPPC	International Plant Protection Convention
$kWh/m^2/year$	Kilowatt per square metre per year
$kWh/m^2/day$	Kilowatt per square metre per day
UNEP	United Nations Environment Program
EJ	Exa joules
PWh	Peta watt hour
USBR	United States Bureau of Reclamation
TWh	Terawatt hour
IRENA	International Renewable Energy Agency

MCDM	Multiple Criteria Decision Making
UTADIS	Utilities Additives Discriminates
IDEA	Integrated Decision Aid
AHP	Analytic Hierarchy Process
GP-AHP	Goal Programming Analytic Hierarchy Process
AD	Axiomatic Design
Mm	Millimetre
EU	European Union
BRG	Back Rio Grande
CR	Consistency Ratio
CI	Consistency Index
GMM	Geometric Mean Method
Gwh/yr	Giga watt per year
kWh/yr	Kilowatt per year
E/kWh	Euro per Kilowatt
GAP	South Eastern Anatolian Project
m/s	metre per second
Wh/m^2	watt per square metre

Chapter 1

INTRODUCTION

1.1 Background of the study

Energy efficiency is one of the most important concerns for all countries and can be seen to be the use of less power in order to supply the same quantity of goods and services. Hence in order to achieve environmental, economical and technological aims, it is important for the countries to be efficient in their supply of energy. According to Patterson (1996), the importance of efficient use of energy as a strategy target is associated with business competitiveness in industries, power security profits and also progressive natural benefits, for instance, diminishing CO2 emission. Moreover Kaygusuz (2010) also mentioned that with efficient increase in energy, there would be an adverse decrease in the use of energy on environment such as CO2 emission, and lower costs of fuels.

There are 1.3 billion people recorded in the world who have no access to electricity access. Record shows that 44% of these people live in sub-Sahran Africa with 38% living in south Asia.(IEA,2011) Therefore, the demand for energy increases daily with the authorities trying to find possible solutions towards providing the efficient level of electricity needed. With an increase in cost and fortification of countermeasures, the circumstance behind raising demands for energy needed for global warming and also for green energy sources becomes recognised. For instance, in last decades, bio-fuels are used as an alternative source of petroleum in transportation sector. In order to examine the world energy condition, primary energy demand should be examined. These primary energies are natural pure energy that has been transformed or converted to secondary energy. Take for instance we have Fossil fuels, nuclear energy, and renewable energy resources such as wind, solar hydro, geothermal and biomass which can all be seen as primary energy (Bent et al. 2002) In 2007, IEA mentioned that, in world energy outlook publication, global primary energy provided an increase of approximately 58% in 25 years i.e. increasing from 7.2 billion TOEs in 1980 to 11.4 billion TOE in 2005.

Although the OECD states were seen to be the centre of energy demand, they had a lower economic and population growth rate than non- OECD nations. Also, it was assumed that, in the future, the demand for energy would increase depending on the growth rate of the economy on emerging market nations such as China, India, and Middle East countries. More important, is the improvement of developing countries which have been recorded with respect to the primary energy and the electricity consumption during last decades.

Table 1: Perspective of World Energy Demand

Items	Energy Demand(M_{toe})				
	1980	2000	2005	2015	2030
Total Primary Energy Demand	7 223	10 034	11 429	14 121	17 014
Transport	3 107	3 649	4 000	4 525	5 109
Petroleum	1 245	1 936	2 011	2 637	3 171
Biofuels	1 187	1 844	1 895	2 450	2 915
Other Fuels	2	10	19	74	118

Source: IEA World Energy Outlook, 2007, 2008

According to IEA(2007), the estimated total primary energy demand increased by 48% in 25 years (from 2005 to 2030). The estimated amount of the total primary energy demand will increase from 11.43 billion toes to about 17 billion toe. However, there are also estimations on petroleum oil which has the largest share of primary energy consumption. The share of the petroleum oil in the world primary energy supply reduced from 34% to 30% and although the quantity of it is estimated as increasing amount from 4.0 billion toe in 2005 to approximately 5.1 billion toe in 2030. It can be also explained as 27.7% increase in share of petroleum oil demand in world primary power supply. Therefore, it is necessary to have a yearly increase in the petroleum oil in order to achieve approximately, 3 billion toe in 2030. However, the peoples demand for bio-fuels rises every year and is predicted that 118 million toe would be demanded by the people in 2030. This shows that there is an incredible rise in the demand for bio-fuels which means that these people would change their preferences from using petroleum to using bio-fuels. In other words, the people would prefer, to use renewable energy resources instead of using non-renewable energy as a result of economic, environmental, social and technological aspects.

Numerically, it was 2 million toe in 1980 but rose to approximately 19 million toes with estimation that there will be a substantial increase of 118 million toe on renewable energy demand till 2030.

Lior (2008) focussed on the consumption rate of the world's primary power which rose to 2.7% in 2005, which happens to be lower than the previous year's rate of 4.4% this led to examining the regional performance with the largest consumption being in Asia's pacific region of about 6% and North America being weakest of about 0.3%. Moreover, in the same study, Chinese demand is given as the largest consumption growth accounting for a higher rate than half of the world's energy consumption growth rate.

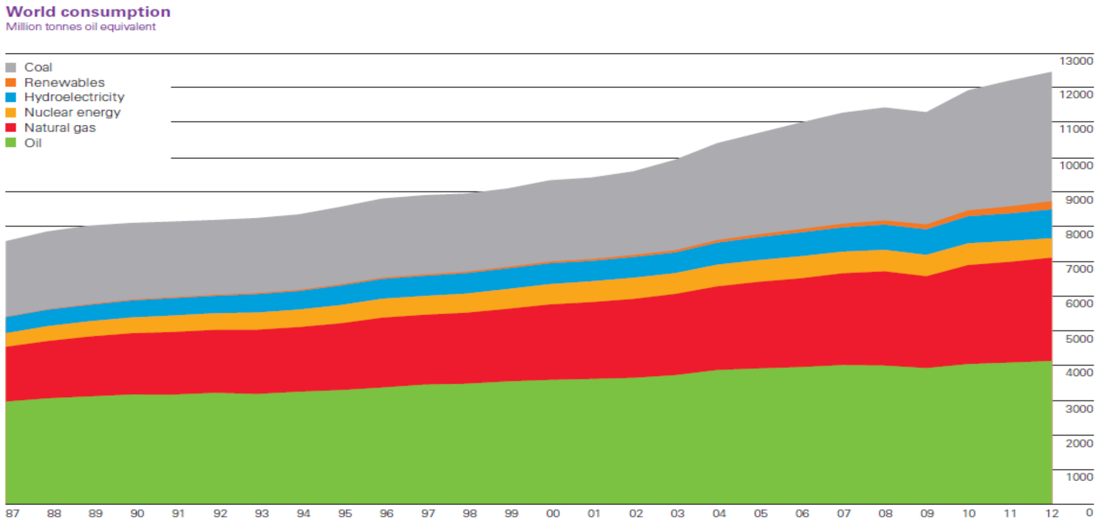

Figure 1: World Primary Energy Consumption
Source: BP Statistical Review of World Energy (2013)

According to British Petroleum statistics (2013), the consumption of the world primary energy increases by less than average except Africa which was recorded as 1.8% in 2012. Moreover, oil is still the world's popular fuel, accounting for 33.1% of global energy with Hydroelectricity and other renewable energy consumption for energy generation reaching 6.7% and 1.9% respectively.

1.2 Renewable Energy

Most of the people do not have an access to electricity or have an inefficient electricity access. They mostly use biomass-based fuels, like crop residues, fuel-wood, and manures. Efficient energy is becoming very important for this issue because it contributes the productivity of households and increases income. Also efficient energy provides families to break out the poverty issue. It contributes countries to generate income, develop itself and increase standards of living for citizens by building schools, lighting streets, internet cafes, building factories etc. Additionally, Akpınar et al. (2008) mentioned that depending on the negative effects of the fossil fuels power plants on the air quality and environment there is a strong argument for developing in renewable energy. Similarly Panwar et al.(2011), mentioned that renewable energy systems increase energy providing, solve energy and water supply, increase living standards, create job opportunities, solve environmental issues, and minimize migration towards other countries.

Renewable energy generally determined as utilization of energies like biomass, solar, wind and hydro for generating electricity and has a capacity for job creation to the citizens. Renewable energy sources can replace the traditional fossil fuels in some areas such as generating electricity, heating water, heating places etc. IEA (2013) explains renewable energy as a power which belongs to natural processes that are renewed faster than their consumption level. Similarly, U.S Energy department (NREL, 2001), mention that renewable energies use sources of energies that are renewed continuously depending on nature such as sun, wind, and plants. Additionally, solar, wind, hydropower, geothermal sources and some kinds of biomass are given as forms of renewable energy. Tester et al. (2005) classified energy resources as renewable energy if it is always available without degeneration and depletion.

For a short while, some of the renewable energy sources counted as depletable. For example, the solar energy is received only for specific time in a daytime. For a long time, solar energy renewability belongs to the appearing of the sun. The other renewable energy sources availability can vary depending on the seasonal situations in factors that produce them.

Additionally, geographical location is one of the other factors that affect the quality and quantity of them. For instance, the countries that are close to earth’s equatorial line would have higher solar radiation for photovoltaic electricity generation than the countries that are far from equatorial line.

Renewable energy usage serves as intends to differentiate the global energy source in order to reduce the over-reliance on a source and will keep the vulnerability that comes from the inaccessibility of the resources. So, seeking the alternatives for the fossil fuels resources is not necessity that the globe is working for oil supply, but, because of the negative effects on the environmental issues and the global pollutions, when the whole countries belong to the fossil fuels to satisfy energy needs. The demand for renewable energies shows rapidly increase because of increase in technologies in industrial zones. World has endowed renewable energy sources which can be convertible to the energy and distributed widespread. However, the implementation cost for generating electricity from them is one of the major limitations for increasing the renewable energy using in the world. However, nowadays, according to the policies and subsidies that the authorities put, the costs of some renewable energy technologies starts being competitive with the costs of conventional power technologies that changes on average from 4 to 10 cents per kWh.

Table 2: Cost of technologies by source

Technology	Typical Characteristics	Typical Energy cost (US cents per kWh)	Comment
Large hydropower	10-18000 (MW)	3-5	Today, the cheapest, largest, and most mature form of RES
Small hydropower	1-10 MW	5-12	Water body is needed
Onshore wind	1.5-3.5 MW	5-9	For power generation it depends to site
Offshore wind	1.5-5 MW	10-20	Blade diameter:70-125meters
Biomass	1-20 MW	5-12	Vastly used in rural areas
Geothermal	1-100 MW	4-7	High initial cost, low operating cost; effectiveness is site dependent
Roof top solar PV	2-5 kW peak capacity 200 kW to 100MW	17-34 15-30	The fastest growing renewable energy technology worldwide from 2000 to 2011
Concentrated solar power (CSP)	50-500 MW(trough) 10-20 MW (tower)	14-18	Costs for trough plants are lower with increasing plant size
Biomass heat for hot water heating	1-20 MW	1-6	Most cost-competitive renewable energy for heating

Source: Edenhofer, O. (2011) , REN (2008)

There are large numbers of renewable energy sources for electricity generation and the implementation of the technologies for generating electricity from renewable energy resources are decided with respect to its costs, quality and operation. Belongs to number of people in the country, potentials of the renewable energy resources and customers affordability the technology for energy generation may satisfy the demand more than other resources. It can be shown as:

Table 3: Energy Services and Generation Income

Energy Services	**Income-Generating Value of Household and Enterprises**	**Renewable Energy Options**
Irrigation	Better yields; higher value crops; greater reliability,; growing during periods when market prices are higher	Wind; Solar PV; Biomass
Illumination	Increased working hours	Wind; Solar PV; Biomass; Micro hydro; geothermal
Grinding, Milling, Husking	Creation of value added product from raw agricultural commodity	Wind; solar PV; Biomass; Micro Hydro
Drying, Smoking (Preserving with process of heat)	Creation of value added products preservation of produce to enable sale to higher-value markets	Biomass; solar Thermal; Geothermal
Refrigeration, ice making (Cold Generation)	Preservation of produce to enable sale to higher-value markets	Wind; Solar PV; Biomass; Micro hydro; geothermal
Extracting	Production of refined oils from seeds biomass	Solar thermal
Transport	Access to markets; public transports	Biomass (bio-fuels)
Computer, Internet, Telephone	Access to market news; entertainment; coordination with suppliers and distributers; wealthier information	Wind; Solar PV; Biomass; Micro hydro; geothermal
Battery Charging	Wide range of services for end users	Wind; Solar PV; Biomass; Micro hydro; geothermal

Source: Adapted from Kumar et. Al and tabled by Flavin et. al REN21

In order to have more sustainable future, implementing more renewable energy technologies and the policies for the energy services will increase the current energy efficiency and the productivity. Moreover, for a long term, using renewable energy will not damage environment and the globe like fossil fuels, thus will affect the sustainable development and the quality of natural resources such as water and forestry.

From 2000 to 2011, cumulative renewable energy installed capacity of world has grown by 72% (from 748GWh to 1285GWh). Additionally, in 2011, top countries with installed technology of renewable electricity was listed as the top country was China and followed by United States, Brazil, Canada and Germany. When installed capacity of renewable energy technologies in the world is examined by sources, the top countries can be listed as (NREL, 2013):

Table 4: Top countries depending on renewable energy technologies' installed capacity in the world

Solar	**Hydro**	**Wind**	**Biomass**	**Geothermal**
Germany	China	China	United States	United States
Italy	Brazil	United States	Brazil	Philippines
United States	United States	Germany	China	Indonesia
China	Canada	Spain	Germany	Mexico
Japan	Russia	India	Sweden	Italy

Source: NREL.2013

1.2.1 Renewable Energy Sources

Those sources can be listed as: solar energy, wind energy, biomass energy, and geothermal energy, hydropower energy, ocean energy...

1.2.1.1 Solar Energy

Solar energy is a power that comes from the sun lights which using for heating, lighting, generating electricity etc. and collected by panels. In other words, solar energy is a transformed energy that is converted from sun's energy into functional form like electricity or heat. The amount of the solar energy depends on geographic location, day time, season, local landscape and weather.

According Crabtree and Lewis, (2007)The Sun gives the Earth an amazing measure of energy that is enough to power the incredible oceanic and air vaporization, the cycle of dissipation and condensation which brings freshly water, typhoons, storms and tornadoes which can easily ruin the area and reinforced new landscape.

Moreover, they divided solar energy transformation into 3 forms and called as solar electric, solar fuel and solar thermal.

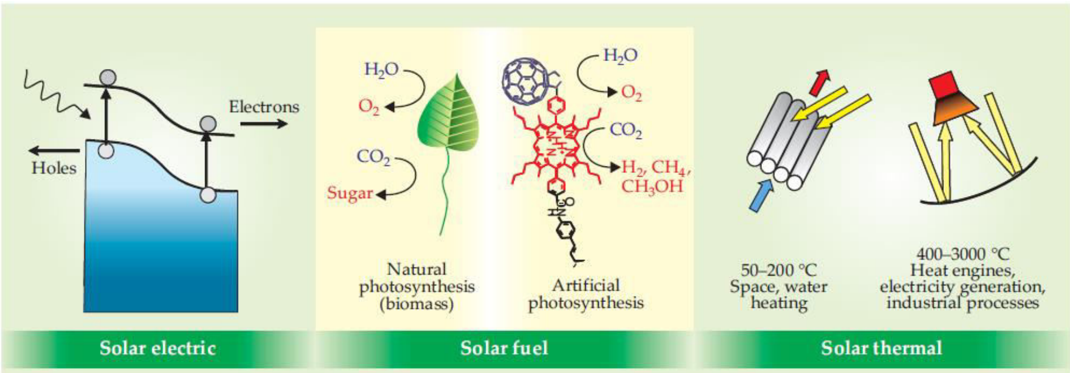

Figure 2: Solar Energy Transformation
Source: Crabtree and Lewis, (2007)

Regardless of the huge supply of energy from the sun, the 3 transformation routes providing just a little part of the present and the future energy needs of the world. According to Turkish Ministry of Energy and Natural Resources (2010), solar energy can be transformed into electricity with using 2 ways: The first way is the Photovoltaic (PV) or solar cells which refers to a changing the sunlight directly into the electricity. Moreover, the other one is to Concentrating Solar Power Plants (CSP). That way belongs to the technology and refers that in order to generate electricity; the solar thermal collectors have to be used which heats the fluid and produces stream. It is used to power a turbine and providing electricity.

However, the states that has huge potentials for solar energy often have the least ability to benefit from it, due to the insufficiency of the capacity and intelligence to harness the sun's power and transform it into the energy. According to Steiner, (2008) the technologies for renewable energies like solar, wind, small- hydro and geothermal power are not installed in the world efficiently regardless of the abundant renewable energy sources and the potentials like sunshine, wind, water and thermal heat.

Benefits: This kind of energy does not cause any harm to the environment. All over the world, the projects are implemented depending on the average daily sunlight and the quantity of solar radiation a particular region can receive in a day. It is free for all citizens that once implemented the panels to the rooftops or to the area.

Drawbacks: This form of energy is very expensive and needs large area in order to generate small sized electricity. When the sun is down, the panels stop generating electricity which automatically means the storage of electricity in accumulator, or use of another source for a certain time would be required.

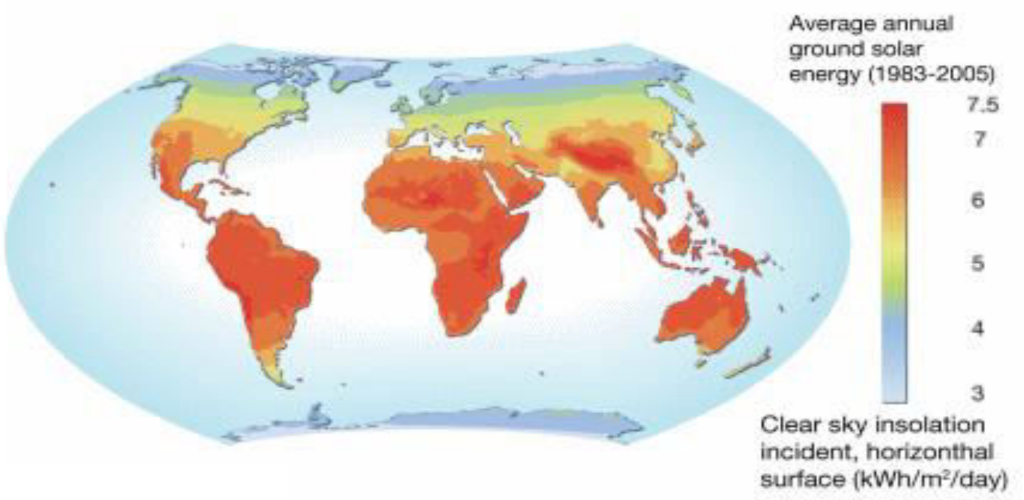

Figure 3: World map of potential solar power (solar insolation in kWh/m2/day)
Source: (Hugh Ahlenius, UNEP/GRID-Arendal Maps and Graphics Library)

The figure shows in the Earth Africa, South America, with Australia having on average annual solar energy potential of about 7 kWh. Despite this, the world still does not reach the efficient level of the installed capacity for this source and its contribution to the gross electricity generation of the world being only around 0.54% which is calculated by International Energy Agency (IEA) in 2009.

According to the study of Grimshaw and Levis (2010), most of the developing countries have a huge potential of solar energy such as Africa which has about 325 sunny days in a year and on average delivering potential is above 6 kWh/m^2/ day

Also Grassl, (2009) a joint German and Jordanian company, predicts that implementation of the solar energy panels in only 1% of the world desserts, can satisfy the power needs of whole world.

1.2.1.2 Biomass Energy

Biomass is a biological stuff that can be gotten from natural organism. Therefore, Biomass power is an energy realized from organic wastes that would be eaten, burnt, or converted into fuels. As an energy source, biomass can be either used directly in order to provide heat or indirectly after transforming it into bio-fuels.

Wood stuffs are used as a largest source of biomass such as wood, wood chips etc. Goldemberg & Coelho, (2004) mentioned that there is an argument about traditional biomass and that issue shows whether traditional biomass is a replenished resource or not. Moreover, some of this type of biomass sources using with a non-commercial aim, which comes from unsustainable sources, are called traditional biomass, and where the source of biomass is manufactured in a sustainable way, it is called the modern biomass (i.e. bio-gas, bio-ethanol etc.). Therefore, common biomass sources, which include both traditional and modern biomass, are represented in below Figure 4.

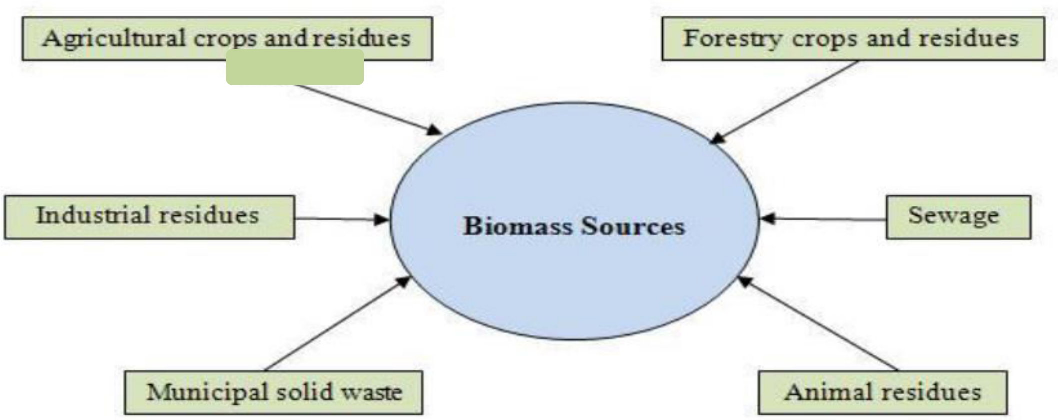

Figure 4: Biomass Sources
Source: Ahmed, Nasri, & Hamza, 2012

Biomass sources have been the most crucial renewable source of energy all over the world. As a primary source of power, biomass energy resources have advantages over fossil fuels because their pollution emissions are less than the fossil fuels. Furthermore, Hashiramoto (2007) talked about wood sources of biomass and emphasized that is the major type of biomass that is used all over the world. In the past, most of the countries tried to take advantages of biomass opportunities and make them more attractive with a comparison to other sources. Depending on this issue, people started to prefer biomass products and consumption of traditional and modern biomass increased rapidly. According to Sims (2003) and similarly Hashiramoto (2007), those countries, relating to sustainability of power supply, dedicated to Koyoto Protocol, (i.e. that force extra cost for carbon as a consequence of rise of carbon trading, the cost of fossil fuels and "carbon-lean" biomass being more competitive, with an increase in the prices for fossil fuels) that have been a dominant influence on recommendations of loads of wood materials.

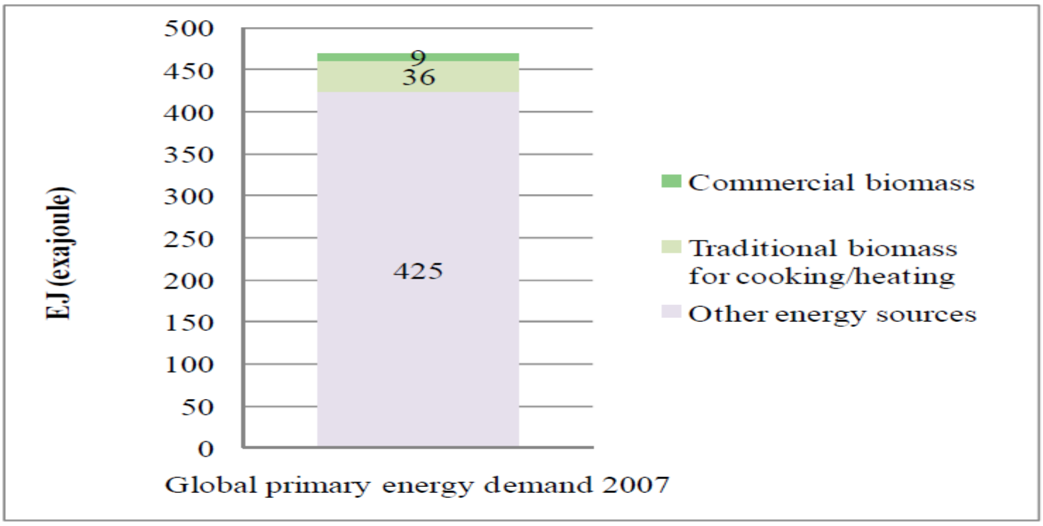

Figure 5 Contribution of Biomass To Global Primary Energy Demand
Source: (*Faaij, 2008)*

According to Faaij (2008), biomass energy contribution to world primary energy demand is four hundred seventy exajoules (EJ) in 2007. Accounted only 10%, and mainly as a traditional form. Compared with other renewables, it is the major renewable source that is used all over the world. Similar to Faaij, Surmen(2002) ranked biomass sources and placed at 4th largest source of energy after coal, oil, and natural gas. However, depending on the demand for energy, there will be extra land availability requirement for the future consumption. Today, the land amount for biomass is only about 20 million hectares or as a percentage value, it is only 0.19% of whole world land area which is 13.2 billion hectares

As a result, biomass is the 4th largest used energy resources in the world after coal, oil and natural gas, which has estimation for annual potential for total world production between 33 and 1135EJ. Moreover, most of the countries promote these resources in order to get the advantage in opportunities and achieve sustainable development in energy sector and development of itself.

1.2.1.3 Wind Energy

Wind energy is an affordable resource and continuously growing sector for the generation of electricity. It is pollution free and competitive as a way of cost compared to coal and gas-fired production. Wind energy is a kinetic energy in nature and captured by turbines. Then, it is transformed into the energy by generator in order to provide electricity to the grid. Therefore, Wind energy has been recorded as a fastest growing energy sector since 1990s in terms of a percentage of annual development of installed capacity per wind energy technology. Ackermann and Soder (2002) mentioned that, at the end of the 1995, the total worldwide installed capacity was 4,844 MW but at the end of the 2001, it reached to 23,270 MW. At those days, the largest distribution of the world wind energy production was about 80% which belonged to North America. However, in 2007, it reduces to 22.9% and replaced with Europe production accounted as 61% of world wind energy production. (Kaldellis & Zafirakis, 2011)

The figure 6A represents the global map of onshore wind potential and shows that the maximum amount of the wind energy potential is in Russia following by Australia and North America. The potentials for these countries are accounted as 116 PWh, 86 PWh, and 78 PWh respectively.

Therefore, the order of the wind energy potential changes with respect to offshore potentials and Russia again comes first with a potential 23PWh, and therefore Canada and United States follow with accounted potential 21PWh and 14PWh respectively. Hence, centre of the Africa, South-west of Asia, and north part of the South America accounted as low potential of onshore and offshore wind energy potentials.

At the global perspective, wind power capacity reached 283Gwh and mostly installed in China, which is accounted as approximately 80GWh, followed by United States of America and Germany recording more or less 60GWh and 35GWh respectively. Moreover, only in 2012, China installed 13GWh extra and US installed more than 13.1GWh to increase capacity and provide sustainable energy to the grid. (REN 21, 2013)

Benefits: Wind energy is less harmful to nature and seen in many parts of the country and world.

Drawbacks: Wind energy is costly and needs more treatment, it is noisy and stops the plant while damaging the system

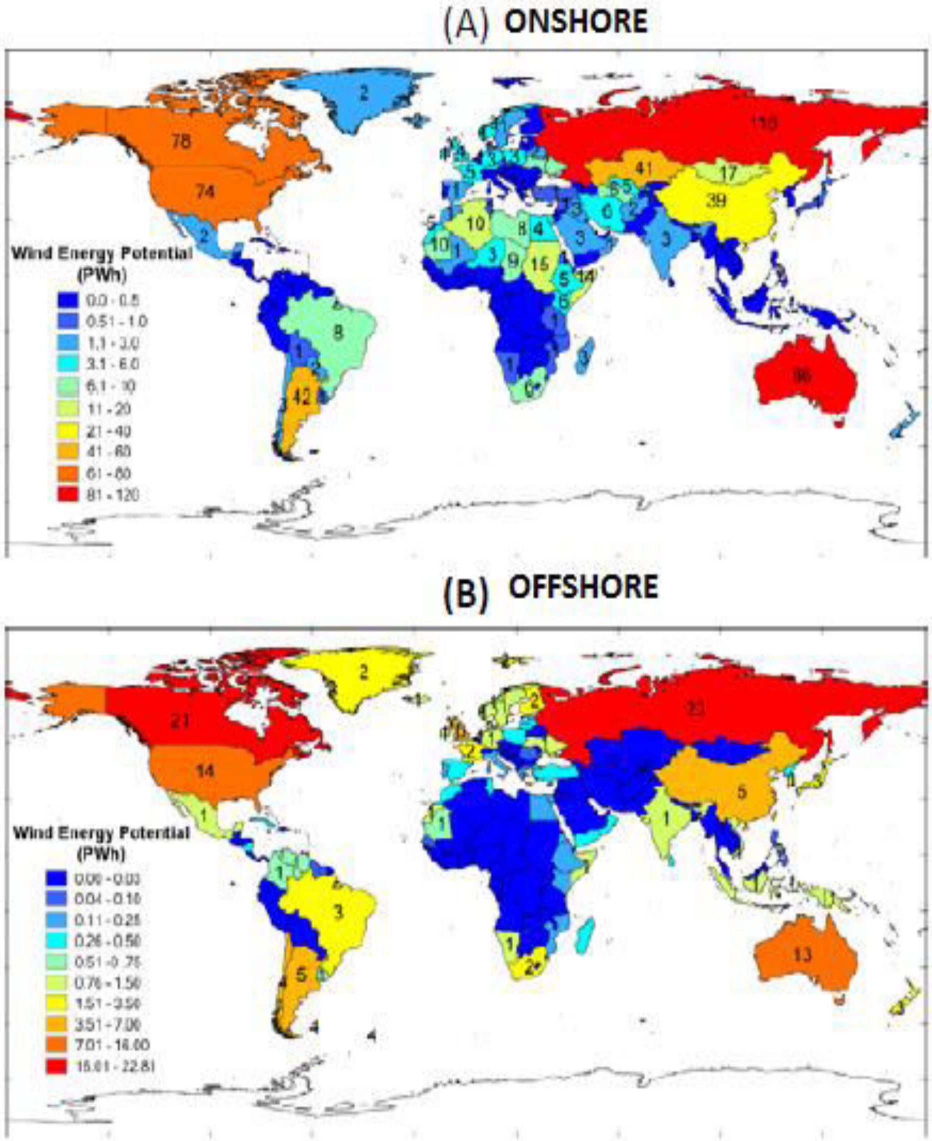

Figure 6: Global wind energy potentials: A- onshore and B- offshore
Source: Lui et al. (2009)

1.2.1.4. Hydropower Energy

Hydropower is the energy produced from water movement and its speed. USBR (2005) defines hydropower as an energy source which can be renewed that utilizes by flow of water. It uses dams in order to pound water from river which turns turbines and produce electricity by generators. Hydroelectric power has a crucial role about sustainability in energy and provides benefits to the integrated system. However, it also has the bad side effects on social and environmental aspects. Accordingly, there is a debate about hydropower resource whether it is renewable energy or not. Because it has negative effects on environmental issues such as blocking natural life, blocking migration of fish, temperature, water quality, water stream etc.

Its implication scaled with respect to the capacity of river and its speed like small hydropower plants and large hydropower plants.

Small hydropower plants which capacity is smaller than 15MW even do not cover storage. However, it has considerable effects on ecosystem of river. Obviously, a large number of small hydro plants may have a negative effect greater than large plants on environment and social issues. However, small hydropower dams have a crucial role for developing regions which provides sustainable energy to the grid and can be cost effective to provide electricity to rural areas. Additionally, large scaled hydro dams are implemented for producing electricity for public. These dams capacity is greater than 30MW which can negatively affect the quality and flow of water, wild life etc. Besides, hydropower is the mostly implemented and cost-effective green energy source in the world, recorded for 16.5% of world electricity and approximately 85% of total green power generation. (IEA, 2011)

Therefore, at a global perspective, According to IEA (2008), the electricity generation by hydropower is largest in Asia and Oceania, accounted as one fourth of the global hydropower supply and followed by North America as 23% and central and South America as 21%. Furthermore, Middle East has the lowest hydropower generation as lower than 1% of total world generation by hydropower.

When hydropower potentials are examined by region approximately 70% of Australia has hydropower potentials and 75% of Europe, 69% of North America 33% of South America and 22% of potentials of Asia.

Benefits: the electricity generation from this energy source does not create the pollution for the air and also has minimum risk for the environment and the water is not much damaged

Drawbacks: When the dam is built it can create the flood which moves people and animals in that region.

1.2.2 World Renewable Energy Generation

As stated earlier, energy is one of the most important factors for a sustainable development of the country. Today, most of the energy demands are satisfied by the fossil fuels like gasoline and coal. However, because of the decreasing amount of reserves, high costs, and the negative effect of using non-renewable energy resources on environment, air pollution, deforestation and imbalance of ecosystem, renewable energy and environmentally friendly resources, which can replace fuels, come into prominence and become crucial. Using environmentally friendly energy resources decreases the CO_2 emissions, and the dependence of fossil fuel importation.

According to World Bank development indicators records, approximately 82% of the total energy consumed as a fossil fuels which compromises coal, oil, petroleum and natural gas. For utilization of the fossil fuels, mining, combustion and the processes cause pollution, destroy water and soil, and surrounding ecosystems. In some parts of the earth, where crude oil is mined, petroleum has also blocked the sustainable development of the country. Depending on this reason, and for reducing the fossil fuels importation, most of the countries have preferred to implement renewable energy sources technology with respect to their potential sources.

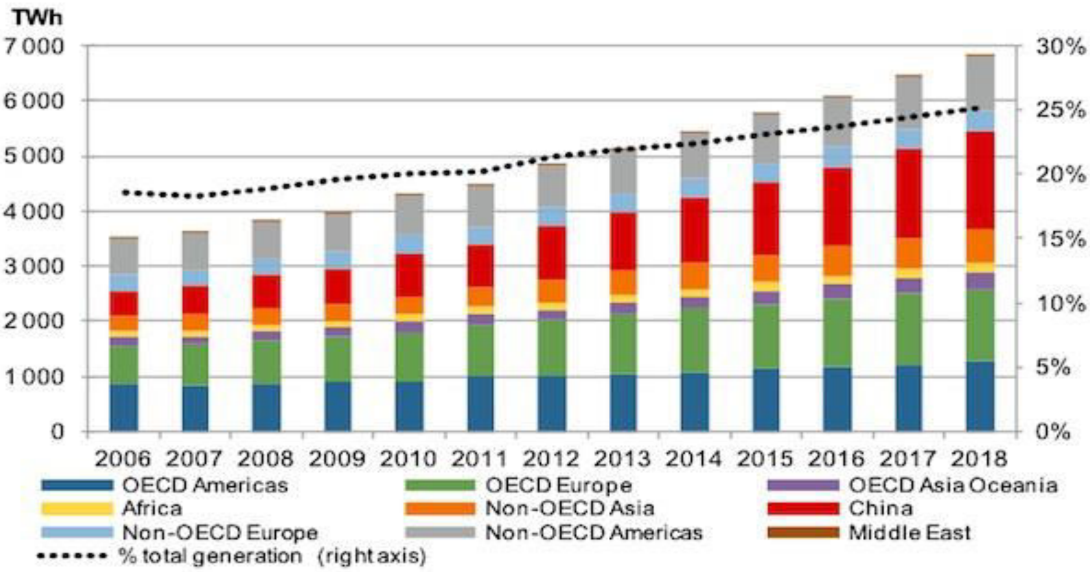

Figure 7: Global Renewable Electricity Generation by Region
Source: International Energy Agency (IEA) (2013)s

Depending on IEA report, more than 20% of the total electricity generation in the world are provided by renewable energy and predicted that it will reach by 25% in 2018. It is expected that from 2012 to 2018, the growth rate of electricity generation by renewable energy is 6% per year and totally 40% rising in generation is expected. Numerically, it is estimated that the total electricity generation from renewable resources will increase from 4860TWh to 6850TWh. In recent years, when examined by the region, renewable electricity production is mostly generated in OECD Europe countries but estimated that China alone will generate more than the other countries and be a top country in renewable energy generation. Moreover, in recent years, when regions are ranked, OECD Europe countries be a top countries followed by the OECD Americas and China.

Therefore, when the current generation by the renewable are examined, it is accounted as in 2010, 20% of the total energy generation by renewable energy resources are measured as 16.35% comes from hydropower, 1.78% solar and wind energy, 1.54% from bio-fuels and wastes and 0.32% from geothermal resources. (IEA 2012)

Therefore, when economic perspective is examined and employment taken as a case study, Global green job estimated and recorded as 3.5 million all over the world in 2010. Also, the green jobs are also estimated by sources and recorded as wind energy create 630,000 and solar PV 350,000 and followed by solar thermal and bio-fuels with 600,000 jobs in 2006 and 1.5 million in 2010 respectively. Additionally, green jobs creation is estimated for top countries which generate higher energy from renewable and ranked as China, Brazil, Germany, India, and the United States. (IRENA, 2012)

1.3 Statement of Problem

Nowadays, the energy system of the countries, especially small island countries, is based on the extracting highly concentrated types of power we can find in the nature like fossil fuels, water power, wave power, fuel-woods etc. And those play a key role in the ecosystem. According to this, an increasing demand for energy and industrialization causes deforestation, ocean acidification, mass poverty, pollution disease etc. Those problems are caused by our energy exploitation. Moreover, using the old technology and generating energy from them cause the same problems on the nature, environment and human beings. Renewable energy can be the solution for these issues. On the other hand limited land capacity, financial restrictions, limited resources and infrastructure causes countries to be dependent to the other nations which reduce the economic welfare of the citizens and the economic development and growth at the same time.

1.4 Significance of the Study

Selecting the best alternative energy resource which is renewable for the current energy generation system is set as the main goal in order to achieve healthy economic development and growth therefore, the other thing is that this study is providing the way to the authority to select the best alternative renewable energy to invest, reduce the dependency to other country, to create jobs, improve public health, stabilize energy prices, reducing the global warming and to have healthy economy.

1.5 Organizational Structure of the Study

This work is framed into the eight sections. Of which the first chapter addresses the background of the study and the general information about renewable energy and the four potentials such as solar, wind, biomass and hydropower. Also, this chapter indicates the statement of the problem and the significance of the study.

The next chapter, Chapter two, provides the literature review which is related with the research question and the model that is applied.

In the third chapter, selected small islands' current energy situations are analyzed and it gives the general overview of the description of the island potential renewable energies and the current energy situations.

In fourth chapter, it presents the methodology for analyzing research topic. Multi-criteria decision making method is selected as a main methodology and Analytic Hierarchy Process is applied in order to reach goal and see the priority levels of criteria, sub-criteria and the alternatives for each islands.

In Chapter five, it represents the objective of the study and examines all objectives with respect to research question, criteria, sub-criteria and the alternatives separately.

The next chapter, Chapter 6, covers the empirical analyze of the study and covers the matrix format representations for the model for each island.

Chapter seven presents the results and the findings of analyze for each island and for each alternatives.

Finally, the last chapter, chapter eight gives the summary of findings and the present policy recommendations and the conclusion of the study.

Chapter 2

LITERATURE REVIEW

Energy is of great necessity to the people. However; it is limited in the world and presently causing environmental destruction through the use of technologies. Therefore, renewable energy is a basic solution for sustainable, environmental friendly, and cost- minimized source of energy for long term future. In order to choose the most appropriate alternative resource for a country, there are many applicable methods. One of those and most useful method is multi-criteria decision making (MCDM) method. It evaluates the best alternative renewable source with respect to social, technological, environmental and economic factors. According to (Afgan & Carvalho, 2002) selecting a suitable energy resource is an issue which contains disparate factors and policies. Taking a decision on renewable energy is a major problem on multiple criteria. Moreover, this issue should be considered because of rising disturbance on the factors of economic, environmental, technical and social. MCDM methods offer specific tools used in handling and bringing wide scaled indicators together also it provides an appropriate assistance for making a decision in explaining the problem in details. Cavallaro, (2009) applied multi-criteria method and demonstrates that it proffer a tool that helps make technical-scientific decision and is able to make decisions clearly and particularly in green sector of energy.

2.1 Multi-criteria decision making method

Pohekar and Ramachandran, (2004) mentioned that multi-criteria decision making method is section of a model which can deals with qualitative and quantitative research to analyse criteria and decisions.

Diakoulaki and Karangelis, (2007), identified 4 scenarios of Greece electricity generation system and all good and bad effects are characterized for generation with comparing renewable energy sources at a point of economic, technical and environmental performances. Multi-criteria decision analysis and cost benefit analysis were used as comparative techniques and found that renewable energy sources are the most appropriate sources for Greece electricity generation.

Cavallaro (2010)using multi-criteria method as an appropriate method to analyse the photovoltaic system and the best choices in green sector of energy distinctly and persistently.

Midilli et al. (2006)worked on green energy impact ratio and renewable energy sectors effect to the countries. Consequently, they used seven strategies and tried to explain the sectoral, technological and application impact of green energy for countries and there positive effects on economies.

Diakoulaki et. al., (1999)used UTADIS(utilities additives discriminates) method as multi-criteria decision making method to examine the factors to determine the capacity of state for using the resources of the energy and conclude that UTADIS method is a strong method to examine extended range of true settlement situation.

Hobbs and Horn (1997) used various MCDM methods in order to create some recommendations for planning the energy generation and policy via an interview and argument between stakeholders. The writer examined the difference among MCDM for evaluating criteria and alternatives equivalents of legitimate all criteria. Consequently, they decided that the best attitude is the combining both methods in order to reach best selection of energy generation.

Topçu and Ülengil (2004), worked for selecting a useful competent energy stock alternatives for Turkey with using Multi-attribute decisions. Therefore, Integrated Decision Aid (IDEA) framework also provided for most appropriate selection of Multi-attribute method and shows rating options and robustness analysis as suggestions to jurisdiction. As a result, wind energy alternative found as a best alternative resource and followed by hydropower and photovoltaic sources.

Moreover, Köne (2007) purposed to have environmental protection and the sustainable energy producing in Turkish energy sector, which is analysed by using Analytical Network Process with putting 2 scenarios. As a result of this study, Hydropower is founded most important alternative resource for Turkish energy sector in order to reach that aims.

Barış and Kucakali (2012) examines Turkey's renewable energy resources where hydropower, wind and geothermal energy potentials are high and tried to explore best renewable technology and most suitable alternative for Turkish energy sector by using multi-criteria analysis. As a result of this study, they found out that Biomass is most appropriate one for Turkish sector according to greatest social benefit of it.

Lund, H. (2007) studied on the renewable energies to make strategies as a way of how to create sustainability in development. Those strategies include 3 important changes of technology: energy saving on demand perspective, efficiency in generation, and subsidizing the fossil fuel with renewable. As a case of Denmark, in this paper, the perspectives and problems of converting all the energy generations system into the renewable energies are discussed with multi-criteria decision making analysis using EnergyPLAN which is sub-model of MCDM model as a methodology for this issue. Consequently, 100% converting of the energy generation system into the renewable is possible.

Patlizianas et al. (2007) worked with 14 different EU member countries in order to evaluate their optimal renewable energy resources for electricity generation by using MCDM model as methodology. Consequently, they mentioned that evaluated resources with respect to environmental and economic impact, biomass is an optimal resource for the countries and hydropower is a second optimal resource for which country has the potential.

Cavallaro and Ciraola(2005) studied for Salina island, an Italian island, in order to make decision about selecting best renewable energy resource as an alternative with respect to the aspects of economic, environmental, technical, and social. Multi-criteria approach was used for the selection and as a result of the study, wind energy turbines founded as a best alternative energy for the island.

Lund and Mathiesen (2009) studied for Denmark in order to evaluate all renewable energy potentials and its future energy system with targeting 100% of Denmark energy supply by renewable energy until 2050 and 50% energy supply by 2030. According to EnergyPLAN methodology, they found that Denmark has to focus on mostly to biomass resources and secondly to wind power in order to achieve these targets.

Ulutas, (2005)has applied analytic network process method in order to evaluate the best renewable energy resource for Turkish energy sector and examined potentials and current energy situations of Turkey. Consequently, biomass is founded as the most appropriate alternative energy to invest for the energy generation of Turkish energy sector.

2.2 Analytic Hierarchy Process Method

AHP is a standout amongst the most broadly utilized methodologies for multi-criteria choice making issues, created by Thomas Saaty (1980). AHP permits chiefs to model a complex issue in a various levelled structure, acknowledging connections between targets, criteria, and options. AHP has numerous application regions, for example, assessment and prioritization, asset allotment, quality administration, bunch choice making, natural requisition, and so forth. (Forman and Gass, 1999)

Demirbas, Ö. (2013) indicates that energy is such an important issue for a country in order to create sustainability in development. Because of this, he applied Analytical Hierarchy Process as a methodology to choose the most appropriate renewable energy technology to create sustainability in energy sector. As a result of the selection between the renewable energies the most appropriate one is the wind energy.

Ramanathan,R. and Ganesh,L.S. (1995), used an integrated GP- AHP model with nine quantitative and 3 qualitative criteria in order to identify the energy resource allocation for household sector for the Madras, India. According to model, using solar thermal, fuel wood and natural gas is more appropriate renewable energies for cooking, biogas and fuel wood are the most appropriates for water pumping, lighting and household operations.

Daim,T. et al. (2009), studied on the comparison of technologies for renewable(wind) and fossil fuel based generation technologies(coal) in order to decide the most efficient technology implementation for clean energy generation for Pacific Northwest using AHP model. Accordingly, they put location, cost, feasibility and availability as criteria to determine the best technology and found that cost is the most important criteria to implement the technologies for wind energy sector

Chatzimouratidis, A. and Pilavachi, P(2008) purposed to evaluate 10 kinds of power plants, which are based on renewable energy, fossil fuel and nuclear, with respect to their effects on the standards of living of the citizens by implementing AHP model. 5 types of plants ranked and geo-thermal resource comes first and nuclear plants come on the 6th position. Therefore, natural gas, oil, and coal power plants stated among 6th and 10th position under socio-economic aspects.

Kahraman, C et.al. (2009), have examined the best way of energy generations from renewable resources by selecting wind, rain, sunlight, tides and geothermal heat for Turkey. In order to choose, they applied comparative analysis between axiomatic design (AD) and analytical hierarchy process (AHP) as a methodology with using 4 main criteria and seventeen sub-criteria. Furthermore, with using fuzzy AHP and fuzzy AD, they found the same result as wind energy is the most appropriate renewable to invest.

Shen et al. (2010) examined Taiwanese policies on renewable energy development that aimed 3 goals which are energy, environmental and economic (3E goals). Fuzzy AHP were used to rank those goals to show the importance of implementing renewable energy generation system. Consequently, they found out that, depending on the importance level of renewable sources, environmental goals come first, economic and energy goals followed respectively. As a result of this work, non-pumped storage hydropower selected as most appropriate renewable alternative in order to reach those goals with respect to energy and environmental aims and solar energy selected as a second important alternative towards economic goals. Consequently, Hydropower, solar and wind energy are selected resources in order to achieve those 3E goals at the same time.

Amer and Daim (2011) worked on the selection of renewable alternatives for generating energy with respect to economic, environmental, technical and social political issue. AHP model implemented for this issue and Pakistan were selected as case study. Finally, the results showed that biomass and wind alternatives should be emergently implemented for Pakistan power sector in order to have sustainable development.

Daniel et al. (2008) studied on renewable energy sector in India and examine the sector with using Analytical Hierarchy process as methodology in order to rank the energies. Authors use cost, efficiency, environment, capacity, potential, social acceptance and reliability as parameter. For India, They found out that wind energy is the most appropriate energy to satisfy future energy demands and it followed by biomass and solar energy respectively.

Erol and Kılkış (2012) implemented AHP model for selection of the best alternative renewable energy resource for energy planning for Aydın, in Turkey. As a result of this study, they mentioned that geothermal power should be selected for investment and energy satisfaction for this region.

Cristobal (2011) applied Vikor model which combined with Analytical Hierarchy Process model for selecting the best renewable energy corresponding to the Spanish Government energy plan. As a result of this study, Biomass resources founded as a best option and it followed by Wind and Solar thermo-electric as alternative sources.

Ahmad and Taha (2014) investigated Malaysian current electricity generation dependence to fossil fuel. Accordingly, AHP model was applied to offer best renewable energy as an alternative resource for electricity generation evaluating with respect to four criteria such as technical, economic, social, and environmental issues. Moreover, they found out that solar energy is the most appropriate alternative for Malaysian energy generation on the way of economic criteria, and followed by biomass toward social, hydropower as technical and wind resources as environmental aspects respectively.

Ertay et al. (2013) studied on the renewable energy potentials of Turkey with an application of MACBETH and fuzzy AHP model. Authors tried to select the optimal renewable energy alternatives with using those methodologies and at the end of analysing, wind and solar energy founded as the best alternatives for sustainable energy development and providing sustainable energy development.

Akash et al. (1999) worked for Jordan electricity generation options with analysing all potentials. An Analytic Hierarchy Process used as methodology. As a result of this, authors found out that solar energy become the best selection for electricity generation in Jordan which followed by wind power and hydropower respectively. Therefore, nuclear plants found as the worst and followed by fossil fuels for electricity generation.

Kabir and Shihan (2003) presented the work on the selection of green energy sources and technologies for Bangladesh Energy sector. 3 alternatives green energies were examined, which are solar wind and biogas, according to the costs, characteristics, location, environment and social acceptability. Consequently, the results showed that solar energy is the most appropriate alternative for Bangladesh energy sector and biogas and wind energy comes respectively.

Sadeghi et al. (2012) tried to find the suitable renewable energy for the region Yazd placed in Iran. For this aim, two approaches are combined which are Fuzzy AHP and Fuzzy TOPSIS in order to rank the potentials. Finally, the result of this study indicates that solar energy is the best alternative and the most suitable potential Yazd and it is followed by wind. Therefore, hydropower and geothermal resources founded as inappropriate potential for that region.

Ayan and Pabuçcu (2013) applied Analytic Hierarchy Process for Turkish energy sector and potentials. Based on this application hydropower, wind, biomass geothermal and solar energy has examined with respect to economic, social, environmental and energy aspects. As a result of the study, hydro-power comes first and most appropriate resource for alternative energy generation and it followed by wind, geothermal, biomass and solar potentials as respectively.

Phdungsilp and Wuttipornpun (2011) investigated the risk analysing of the electricity generation from different kinds of renewable energy resources with respect to environmental and social issues. Bangkok was selected as a case study for this work. According to this issue, qualitative and quantitative data was analyzed with AHP and as a result, solar thermal energy founded as less risky alternative resource and it followed by PV and biogas. However, municipal solid wastes and biomass sources placed in the top of risky resources

Kaya and Kahraman (2010) aimed to work on two issues which are selecting the most appropriate renewable power alternative and making a selection between alternative region for Istanbul, in Turkey by using combined VIKOR and AHP methodology. As a result, they found that wind energy is the most suitable alternative energy and Çatalca region was selected as the best area among alternative regions for installation of wind energy system in Istanbul.

Gerogiannis et al(n.a)worked with AHP to prioritise renewable resources according to the costs, CO_2 emissions and job creation and efficiency. According to this aim, the survey has been done with economists, engineers, environmentalists and citizens in Greece and the report of World Energy Council. Consequently, wind energy is founded as the most appropriate resource in order to reach those aims. However, Engineers selected the hydropower energy as the most suitable one.

Chapter 3

RENEWABLE ENERGY POTENTIALS OF THE SMALL ISLAND COUNTRIES

3.1 Malta

Same as most countries, electricity generation in Republic of Malta depends on the fossil fuels. Based on records, energy sector is almost 95% dependent on the importation of fossil fuels as at 2011. But of recent, like other countries, Malta started developing its alternative energy investments in order to reduce its dependency on fossil fuels. In 2012, Malta electricity was ranked the most expensive and most polluted in the country. In order to find possible solutions, the authority of Malta decided to integrate electricity from Sicily, in Italy, and after the negotiations, it was interconnected to Sicily Island with 500 MW capacity cable. Therefore, the importance of the company Enemalta, which is the only one producer of electricity in Malta, was increased according to providing efficient level of energy to satisfy energy needs of the citizens. Depending on this interconnection, the government offered its citizens a healthy life, good quality weather, and less costly electricity. After the integration, the efficiency increased by 40% on average. (Buttigieg, 2013) On the other hand, Maltese renewable energy sector is developing yearly. The alternative source for energy generations in Republic of Malta mainly belongs to sun, wind, and biomass. However, According to Malta official data from Enemalta Company, it can be seen that there is no hydropower potentials for Malta and average annual rain that was recorded as approximately 600 mm (24 inches). Besides, Farrugia et al. (2005) mentioned that photovoltaic system in Malta contributed energy to total energy generation as 9.1%, which installed on rooftops, and followed by onshore wind farms with a contribution of 5.4%, offshore wind farms 3.4%. Additionally, energy generated by biomass contributed total energy generation by 5.6% and solar water heating contributed 4.8%.

Therefore, with respect to the World Bank data, total energy production was recorded as 2194 million kWh and per capita consumption was 4684.70 kWh in 2011. Moreover, Maltese base demand for electricity is measured and recorded as 160 MW and therefore the peak demand was measured as 425 MW for recent years. In case of renewable energy resources, the electricity generation from them was recorded as 11 million MW in 2011. As a percentage, it can be represented as almost 1% of the total electricity generation. Depending on the potentials of renewable energy resources, Malta decided to improve its electricity generation by renewable energy sources targeted with European Union to improve its capacity up to 20% by 2020 with their target being 10% for gross consumption and 10% for transportation sector. Also, Debono (2013) mentioned in his study that the estimated amount of green job creation in Malta was 5000 and is planned to increase to 10000 by 2015. Also, in 2007, green jobs, in Malta, were mainly produced by waste and water management fields.

Solar potential

Solar photovoltaic, installed at the rooftops, is mostly used as renewable energy resource for Maltese energy sector in order to provide sustainable energy for demanders and develop its economy. For this reason, solar radiation is been observed continuously. Malta has 80% of sunlight in a year and the radiations were measured at peak amount as almost 8kWh/m^2/day, while it reduces to the lowest 2.5kWh/m^2/day in winter time and annual average of daily light was recorded as 8.335 hours per day.

Malta has an abundance of sunshine, and moderate temperature. However, in reality, having an abundance of the resource does not meaning that producing electricity from that source satisfies all citizen's need because the land capacity and/or the implementation costs are very important factor for building the technology for producing electricity from solar power. In other words, due to the scarcity of the ground base systems and implementation of the solar PV system is limited and it would be implemented on the roof top areas for small scaled islands. According to Buttigieg (2013), Malta has 26Gwh installed capacity per year and has an upcoming project to install 67000 m^2 public rooftops with 4.5 MWp capacity which will generates about 7.5GWh per year.

Wind

Wind energy plays a key role for Maltese energy sector in order to achieve 10% target for producing electricity from an alternative energy resources which are renewable resources by 2020. Malta has higher potential of wind energy in his offshore areas. In fact, offshore wind energy is larger than onshore potentials and assumed that its contribution will be large to the electricity generation. According to Eurobserver database (2010), the contribution of it predicted as a range between 95MW and 216GWh. Therefore, regarding to the incentive policies, up to 3.7kWh urban wind tribunes are subsidized by 25% while the extra generation which connected to grid is purchased with a price of 0.07€ per kWh. Compared to solar photovoltaic, regarding to small land area, which is 316 km^2 and high population per square km (1350 people per square km), especially offshore wind potentials should be considered in order to reach 2020 target.

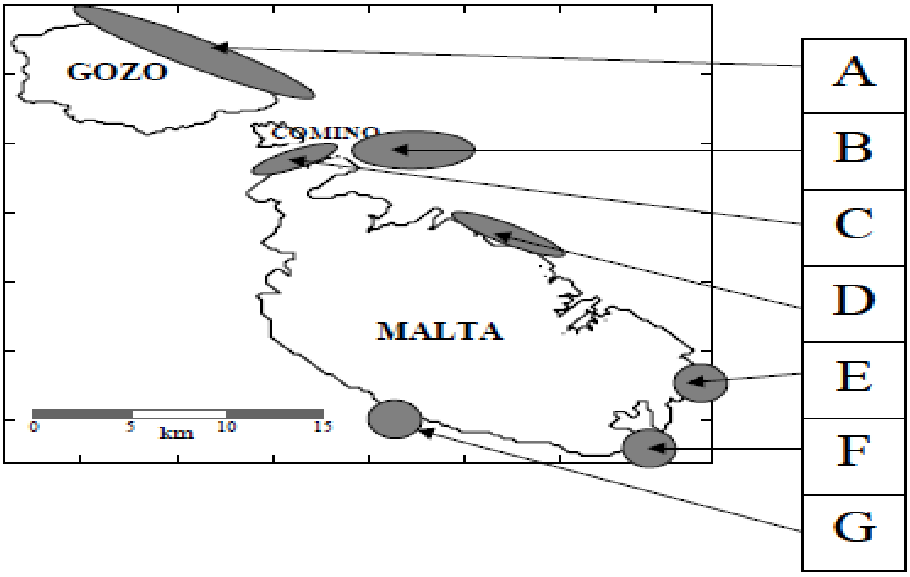

Figure 8: Malta Offshore Wind Potentials
Source: Farrugia et al. (2005)

In the figure above, many regions potentials are evaluated and high potentials are listed as north side of Gozo(A), Sikka l-Bajda(B), Marfa Ridge(C), an area between St George's Bay and Selina Bay(D), Sikka tal-Munxar(E), Benghajsa Reef(f) and the region in the south east part of Malta where named Hamrija Bank(G).

Recently, Maltese authority decided to implement a huge wind farm for offshore wind potentials with 36 turbines which will set on a hexagon shape and have 460 metre-wide platform. The authority has planned to start generation in June 2014. Additionally, it is supposed that, a floating wind farm can be located on North-East of Malta, where depths of sea changes between 100 and 150 metres. It has been planned to be connected to the land by a cable and has an ability to turn 360 degrees in 30 minutes. It is estimated that it will generate 54 MW capacity of electricity which is going to help Malta in order to reach its target. But in 2008, the authority in Malta revised this plan and allowed to develop 2 onshore wind farms in Halfar and Bahrija cities and named these projects as Wied Rini project with a capacity of 10.2 MW and Halfar project, 4.2 MW.

However, Malta is trying to implement wind energy technologies in Sikka l-Bajda region where the offshore potential is measured as 95MW and predicted that it can produce 40% of Maltese target for renewable energy generation by 2020.

According to Malta Resource Authority, onshore wind potentials are evaluated and ranked as Ghenieri region has the highest onshore potential as 44 MW and followed by Wardija Ridge as 40 MW capacity and Bajda Ridge as 36MW.

Biomass

Malta has limited agricultural area and water which are the major constraints for biomass energy. Biomass potential is used as animal waste from pigs, bovine, and others. They are mostly used for heating. Moreover municipal solid wastes are the other important factor that Malta use as biomass source to contribute its energy system. Its potential for biomass is recorded as least attractive potential. Additionally, its solid biomass is ranked and rated as 80^{th} out of 81 countries. (Jossart, 2013)

Hydropower & Geothermal

Malta does not have suitable potentials of both hydropower and geothermal resources that cannot contribute the energy generation of Maltese energy sector. Moreover, investing on hydropower technology in Malta, even it is small, cause the higher cost to the budget of either the authority, or the private investors.

3.2 Cyprus

Cyprus is the third largest island in the Mediterranean Sea which economic activities mostly belong to the services and construction. Mainly, its industry is restricted by food and drink industries and small scaled industries such as cement, ceramics and pharmaceutics. Without any integration of energy and oil gas potentials, its energy sector depends on fuel import and high cost of power imports. Its electricity mostly generated by diesel, heavy fuel oil, and green energy sources. Since 1960, energy policies were recognized as a main issue in order to achieve sustainable development. Like other countries, Cyprus energy sector depends on the fossil fuels and the importation of it is on average 96% of total while almost 100% of the people have an access to electricity.

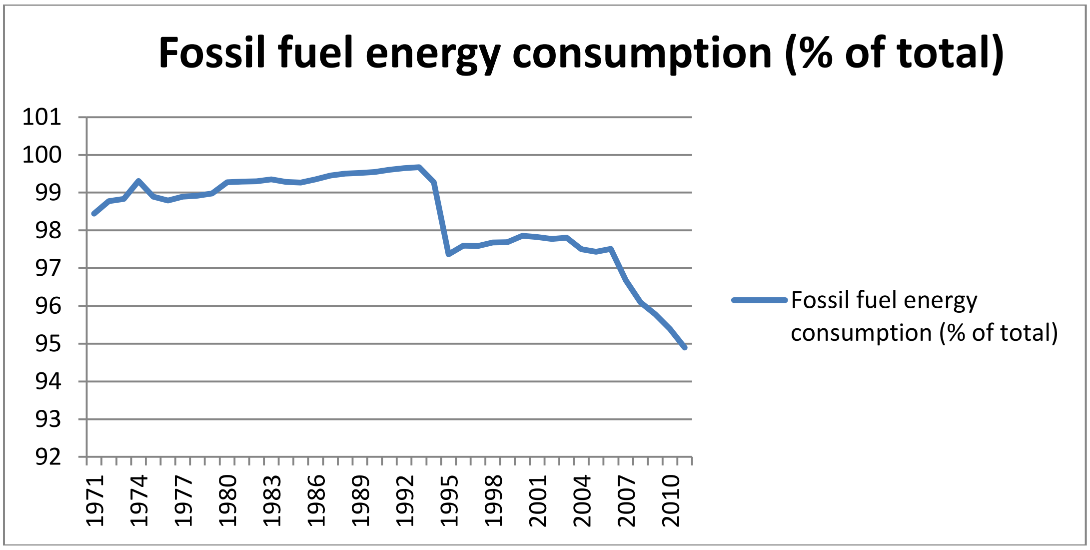

Figure 9: Fossil fuel energy consumption (% of total)
Source: World Bank WDI

As figure shows, the dependency on fossil fuels is above 95%. In recent years, the renewable energy resources become crucial and implementation of renewable technologies rose. Depending on these issues, the consumption of fossil fuels shows reducing rate and decrease from almost 100% till almost 95%. Its electricity generated by fossil fuels in the Dhekelia Power Station with a capacity of 460MW, Moni Power Station 140MW plus 125MW in storage, Vasilikos Power Station 860MW, (Electricity Authority of Cyprus)

According to Pilavachi et.al. (2012) primary energy is generated by oil- based and recorded as 90%, 6% from coal and the rest 4% belongs to the solar power. Also, primary energy consumptions were evaluated according to the sectors and the top is mentioned as transportation sector and followed by the sector of industry.

Depending on World Bank, almost 100% of the Cyprus has an access to generated electricity and total production of electricity was recorded as almost 5 million kWh in 2011 and also for that year the per capita consumption was accounted as 4.271 kWh. With an increasing rate of energy demand, Cyprus reached the peak demand as 997MW. Moreover, since 2003, the law was established by the parliament of Cyprus and 0.3 CYcent/kWh was charged from households in order to create a fund for contributing the new energy sector (Pilavachi et al. 2009)Hence, it is expected that the contribution of Renewable energy is predicted to increase from 3.5% in 1995 to 9% in 2010.

Recently, generating electricity from renewable sources is rapidly grown in the sector. Mostly, solar and wind energy technologies are implemented because of high incentives by authority. There is an estimation by Energy Authority of Cyprus, and the potential is estimated at 150-250 MW and 743 MW application for tribunes installation in 2006. Therefore, the average wind energy is recorded as 5-6 m/s and 6.5-7 m/s. on the other hand solar potentials are also estimated accounted as a daily average of 5.4 kWh per m^2 and 600 kWp of PVs and with respect to the limited resources in hydropower potentials which is counted 1 MW and estimated that yearly energy power of 5-6 GWh/yr.

Wind

Wind energy plays a key role in renewable energy sector in Cyprus for generating electricity. According to Palavachi(2009) the potential was estimated as a range from 150 MW to 250 MW. Moreover, it was measured that in some region, the wind speed reaches to 5-7 m/s. Compared to other countries in European Union, Cyprus has a good renewable energy potential and a very good position for using it. Cyprus uses this potential in order to provide sustainable energy for demanders and reduce the dependency as a way of importation of oil sources. The other issue for using this resource is to provide secure energy.

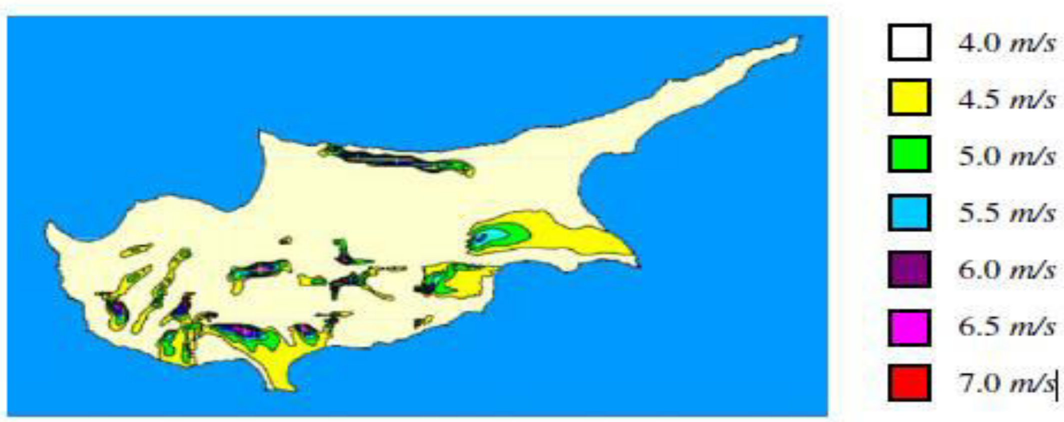

Figure 10: Wind Map of Cyprus
Source: Cyprus Institute of Energy

As figure shows that the wind potentials are mostly seen in the south part of the Cyprus and only on the top of the Beşparmak Mountains in the north part. The winds are mostly recorded from west or southwest side of the country in winter time and north-western or northern part during summer. Therefore, there is four privately built up wind farms in order to generate and distribute electricity for the electricity grid which can be listed as:

Name of Wind Farm	Capacity of Wind Farm
Orites	82MW
Alexigros	31.5MW
Santa Anna	20MW
Koshi	10.8MW

Solar

The contribution of solar energy for water heating was recorded as around 3% of total generation and above 90% if households and more than 50% of hotels implemented these technologies in Cyprus. Moreover, depending on these implementations, Cyprus was ranked as the largest per capita using of thermal energy power and followed by Austria and Greece in Europe region. (Ioannou and Theocharides, 2009) However, Photovoltaic system implementation still limited in Cyprus, where the daily average of the solar irradiation is 5.4kWh/m^2 and potential is 11.5hours daylights per day and reduces on average 5.5 hours in cloudiest days. (Partasides, 2013)

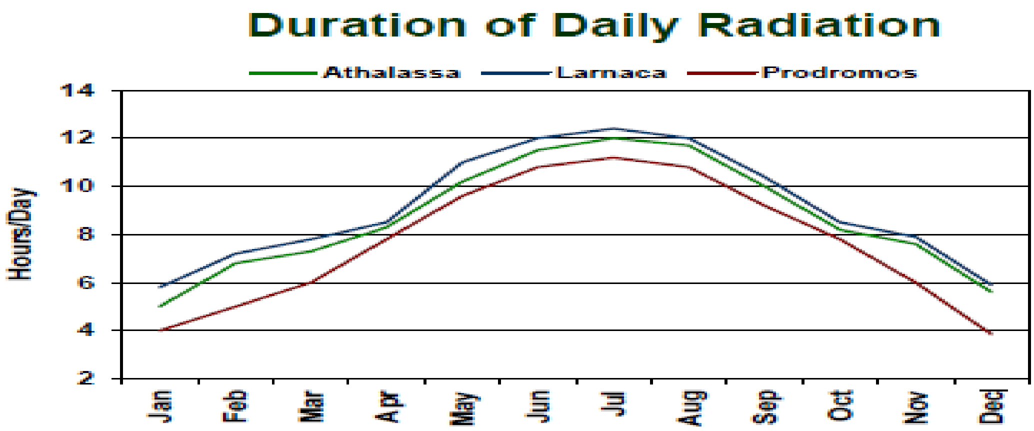

Figure 11: Duration of daily Radiation of selected Regions from Cyprus
Source: Meteorological service of Cyprus

It reaches at the peak duration in the summer time and on July it reaches above 12 hours sunshine per day. Additionally, average solar irradiation differs between 250-700 Wh/m^2. Mostly, the photovoltaic system is implemented in pilot areas such as schools, transmitters of Radio and Telephone. By 2013, above 15MW photovoltaic system installed in Cyprus and approximately 14.5 MW of them has been connected to grid.

Nowadays, it is targetted to install the largest solar energy park into the Limassol region and the cost of it is accounted as approximately 185 million euro.

Biomass

Cyprus has limited land capacity but huge agricultural wastes to use as biomass resource. Other resources for using as a biomass resource can be listed as animal manure, municipal solid wastes, and some other wastes from food and drink industries. Agricultural wastes has a huge capacity in the Cyprus biomass sector and the following graph will show land use of Cyprus depending on the agricultural purposes.

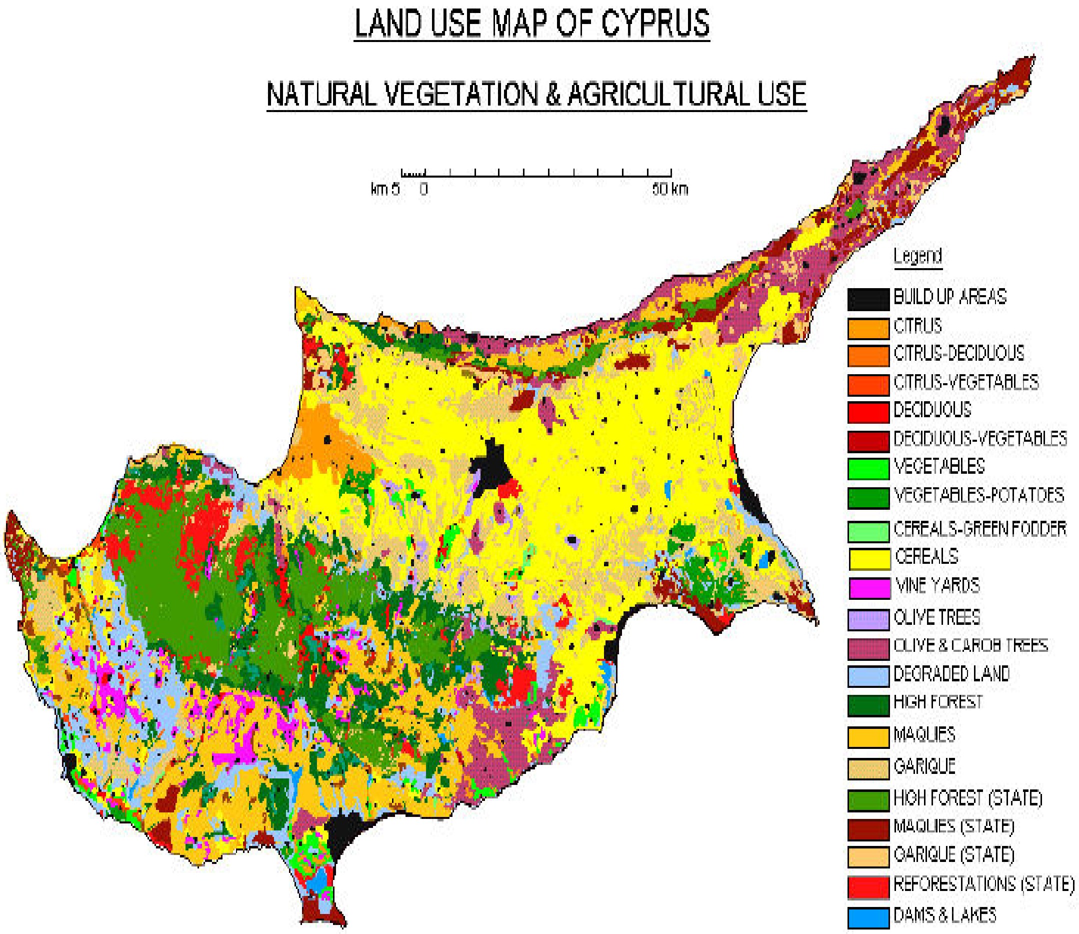

Figure 12: Land Use of Cyprus Depending on Agricultural Purposes
Source: (Cyprus National Report, 2006)

Bimass potentials are evaluated and accounted as 9.2 million tonnes capacity. (Kythreotou, Tassou, & Floride, 2012)Therefore, depending on these resources, there is 8.76 MW installed capacity where they are connected to grid. The amont of grid connected biomass capacity is already recorded as 7.9 and total is expected to be increased to 10 MW by 2013.(Partasides,2013)

Hydropower

Hydro-power potentials are not good enough in Cyprus. It is not expected to contribute the significant energy generation. Because the potential is calculated as 1Mw and on average annually 480 milimetres rainfall is counted which is too low.

3.2.1 Subsidies For Electricity Generation By Renewable Energy Sources

Table 5: Subsidies and the per kWh total purchasing prices of the electricity generation by renewable energy in Cyprus

Investment	Subsidy	Total Purchasing Price
Large wind forms for electricity production		
Large Commercial Systems	Grant 0% only energy produced is subsidized for the first 20 years of operation	€0.166/kWh (Subsidy= 0.166- price of electricity paid by EAC)
Large and Small Photovoltaic Systems for Electricity Production		
Large Commercial PV Systems with Capacity Between 21 to 150 Kw connected to the Electricity Network	Grant 0% only energy produced is subsidized for the first 20 years of operation	€0.34/ kWh (Subsidy = 0.34- price of electricity paid by EAC)
Small Commercial Systems with Capacity up to 20 Kw, Connected to the Electricity Network	Grant 0% only energy produced is subsidized for the first 20 years of operation	€0.36/ kWh (Subsidy = 0.36- price of electricity paid by EAC)
Electricity production from Biomass and Bio-gas produced from landfill disposal sites		
Electricity production from utilization of biomass	Grant 0% only energy produced is subsidized for the first 20 years of operation	€0.135/ kWh (Subsidy = 0.179+0.0171premium - price of electricity paid by EAC)
Electricity production from utilization of bio-gas from landfill disposal sites	Grant 0% only energy produced is subsidized for the first 20 years of operation	€0.145/ kWh (Subsidy=0.0974+0.0171premium- price of electricity paid by EAC)
Large Solar Thermal Systems for Electricity Production		
Large Commercial solar systems connected to the electricity network	Grant 0% only energy produced is subsidized for the first 20 yrs of operation	€0.26/ kWh (Subsidy = 0.26- price of electricity paid by EAC)

Source:(Ioannou & Theocharides, 2009)

As it is seen on the table above, the largest subsidies are given to small scaled commercial PV systems, which capacities are up to 20kWh, with 0.36 € per kWh. And followed by the large scaled PV systems as 0.34 €/kWh. The reason for that can be the highest potential of the renewable energy sources is solar irradiation in Cyprus. Hence, the lowest subsidies are given to biomass and biogas production as 0.135€/kWh and 0.1145€/kWh respectively.

3.3 Cuba

Cuba is a small island country located in the south east part of North America and north east part of South America. Like other countries, its energy sector belongs to the non-renewable energy sources mostly oil and natural gas. About 50% of total energy supply depends to the importation of non-renewable energy sources which is mostly imported from Venezuela.

Therefore, World Bank indicators showed that as of 2011, approximately 95% of the citizens had access to the electricity but only 86% of them are satisfied. Depending on this difference, in order to provide good quality energy and sustainable energy to the citizens who live in the rural area, renewable energy sector become crucial and biomass energy started to play a key role in the generation. Also, in renewable energy sector, biomass energy using mostly sugar cane is followed by the wind energy, solar energy and hydropower. According to Suárez, et al.,(2012) the renewable energy resources that is mostly used can be ranked as biomass with a more than 93% rate and pursued by hydroelectric energy, solar energy and wind energy with a value of 0.6% and 0.06% and 0.04%

Hence, Cuban authority tried to pay attention to wind potential depending on its costs of implementing and environmental effects. Environmentally friendly wind energy and the solar energy massively subsidized in order to improve implementation level and also provide sustainable and efficient level of energy to its households.

Solar

Cuba has large potential of solar PV with wind potential. In the recent years, the implementation programs for solar PV systems have been subsidized by the Cuban authority and non-governmental organizations. The aims for subsidizing the PV systems are firstly being an environmentally friendly source and the system and secondly, help to bring electricity to the rural areas. In Cuba, 6068 photovoltaic systems have been implemented by today with a capacity around 2 MW and mostly household schools, medicals and the cultural placed are satisfied from it. (Suarez et al., 2012)

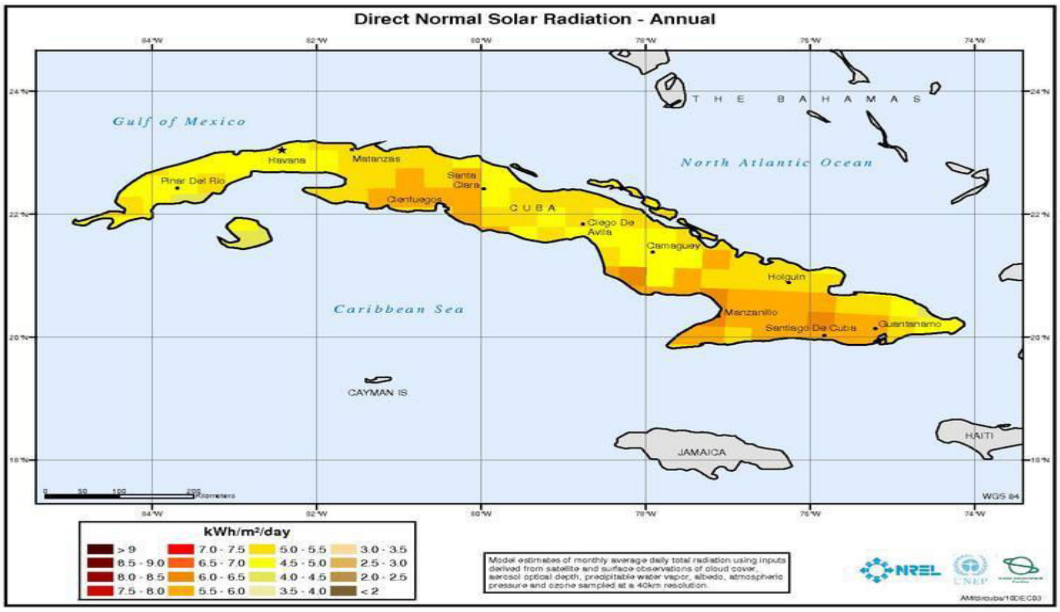

Figure 13: Annual solar irradiation in Cuba
Source: National Renewable Energy Laboratory (2003)

As it is seen on the figure, Cuba has on average 5.5-7 kWh/ m^2 /day solar irradiation, mostly in south part, implementing its solar PV modules to those regions. However, the north part of the island was recorded as the lower potential PV region and implementing the modules to those parts were not beneficial and could not contribute to Cuban energy sector. Käkönen et. al.(2014) mentioned that in Cuba, there is at least 10,000 photovoltaic systems are installed for providing more sustainable energy to isolated areas. It developed the first solar farm in 2013 to the Cantarana region and 14 000 modules were installed to that farm with a capacity of 2.6MWp.

Wind

Wind energy potentials in Cuba mostly used for water pumping and for providing efficient level of energy to the grids. The annual wind speed is recorded by World Bank and announced as 6.2 m/s. Depending on this potential, there are four main wind farms where one of them funded by non-governmental organization and the rest 3 small scaled farms are financed by authority. Those farms include 20 turbines and the capacity of them measured as 11.2MW. Moreover, the wind mills which installed for water pumping is often implementing on isolated areas. Suarez et al. (2012) recorded that in Cuban regions, there are at least 4850 systems installed for wind potential.

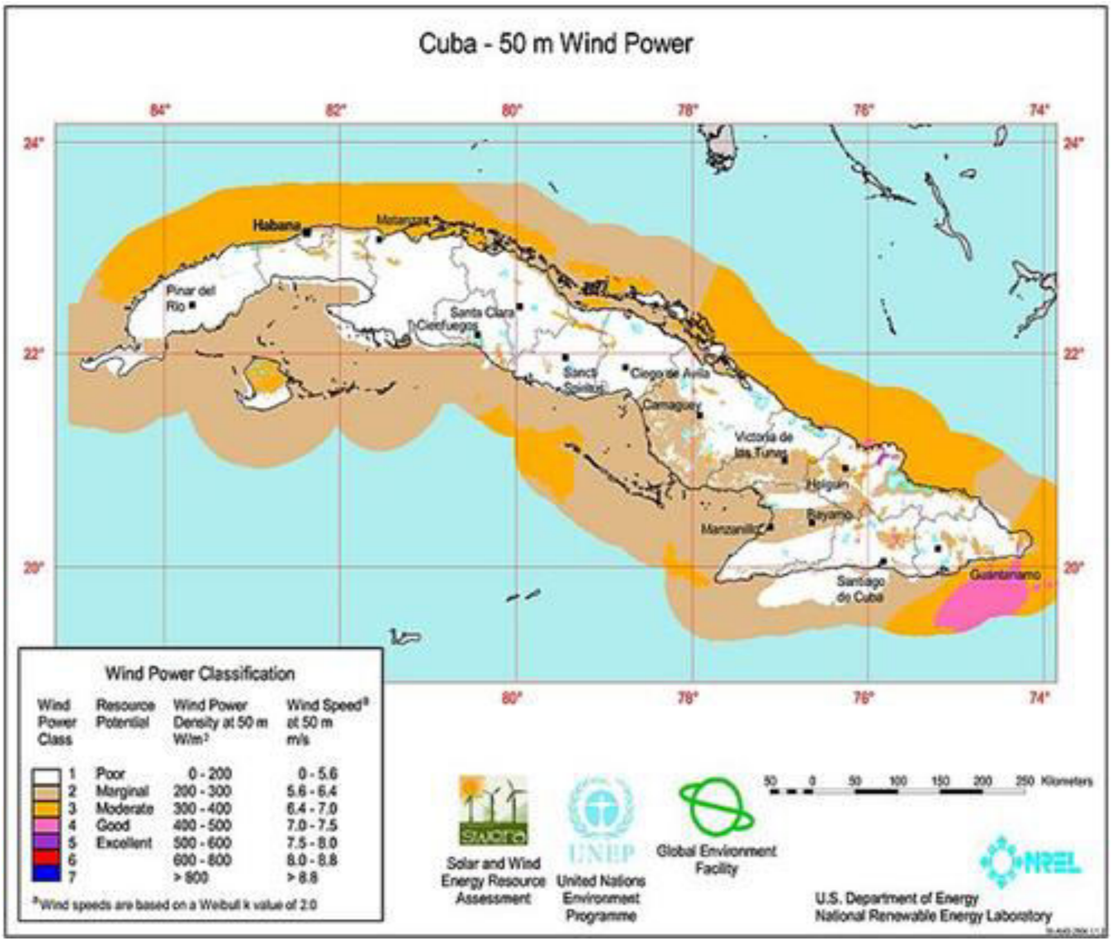

Figure 14: Cuba Wind potential- 50 m
Source: National Renewable Energy Laboratory (2003)

As it shown in figure, the south east part of the Cuba, Guantanamo region, has the highest offshore wind potential and classified as a good potential. And mostly the potential wind power measured from north part of the country and categorized as moderate potential.

Hydropower

The predicted potential of the hydropower was counted as 650 MW but only 10% for them can be used. The reason is explained as the most of the potentials are seen around the secured regions.

Avila (2008), however some other techniques are used for these potentials such as rare pumps, ram pumps etc. in order to provide water to the regions around them. Moreover, there is estimation that there are almost 35 thousand of people satisfied by the electricity generation of the system. (Kakonen et al.,2014)

However, the hydropower potentials create a significant problem for the Cuba because most of those potentials capacity fluctuates depending on the season and the quality of electricity generations from them reduces. Accordingly, their operations are often stopped.

Biomass

Biomass is one of the most important renewable energy potential in Cuba. Cuban biomass potential is well-known by sugar cane. Sugar cane takes huge share of providing energy to the Cuban energy sector. However, nowadays, generating energy from sugar cane started to have a decreasing rate because of decreasing the production level. Sugar cane is used in order to satisfy the energy demand by the production of sugar and ethanol.

The major biomass potential was recorded as sugar cane sugar cane bagasse (48%) and pursued by fuel-wood, biogas, sugar cane straw with the rate of 31%, above 10% and almost 7% respectively. However, only 82% of biomass potentials are used for producing electricity. Those are sugar cane bagasse 59% fuel-wood above 38% charcoal almost 3% and biogas 0.02%. (Suarez et al. 2012)

3.4 Jamaica

Jamaican energy sector mostly depends on the imported fossil fuels and it was accounted as, in year 2011, above 82 %. This dependency causes negative effects on balance of payment and the stability of exchange rate, economic growth and sustainable development etc. When Jamaican energy sector is examined 90% of the country accessed to the energy and the peak demand of the consumers is recorded as above 640Mw while the base load is 400Mw. Therefore, in order to satisfy these demands for energy, Jamaica tries to implement some technological systems on the alternative energy sources. Mostly, it uses hydropower and wind energies as an alternative energy as a solution for having sustainable energy providing and satisfying energy demand.

Recently, Jamaican authority uses more than 6% renewable energy resources out of the total energy generation and targeted to improve this rate by 20% up to 2030. Moreover, the daily solar radiation has been recorded as 5kWh per metre square while the potential of the wind is recorded as 5.8 m/s (Wright,1996) Recently, Jamaica feed the electricity grids by using mainly wind and hydropower potentials and solar energy potentials are tried to be encouraged.

Wind

Further the study made by Wrights in 1996, extra studies has done by the authority of Jamaica and founded that in the years between 1997 and 2004, the wind potentials are re-measured and recorded as 8m/s where it has contributed the energy generation higher than before and proves that in order to satisfy all energy needs wind energy is the suitable energy to invest for the country. Therefore, firstly only one farm was installed in Jamaica and named as Munro wind farm in St. Elizabeth region. Then, Wigton wind farm was installed in 2004 with a capacity of 20.7 Mw which is used for getting benefits from it by reducing oil importation and its environmentally friendly behaviour. (Altomonte et al.,2004)

Hydropower

Depending on the geographical properties of Jamaica and its climate it has many rivers which are suitable for energy generations and implementing either small or large scaled hydropower dams. Hydropower is another important renewable energy resource for Jamaican energy sector. It uses this potential in order to generate sustainable and efficient level of energy to satisfy consumer needs with a total potential of 94Mw. Therefore, only 24Mw was connected to the grid out of 94 mw of total potential.(Patterson, 2007)

In current time, 8 hydropower systems were installed in Jamaica where the aim is to satisfy at least the base load of the consumers' demand which is recorded as more than 400 Mw in a day. Those systems with their capacities can be listed as follows:

Table 6. Hydropower Systems and Their Capacities in Jamaica

Scheme/ Location	Capacity(MW)
Back Rio Grande(BRG)	50.5
Back Rio Grande (Upper)	6.0
Rio Grande	3.9
Great River	8.0
Laughlands Great River	5.3
Rio Cobre	1.0
Negro River	1.9
Yallahs River	2.6
Wild Cane River	2.5
Morgans River	2.3
Green River	1.4
Spanish River	2.3

Dry River	0.8
Martha Brae	5.4
TOTAL	**93.9**

Source: Ministry of Energy, Mining and Telecommunication

As it can be seen on the table, Back Rio Grande (BRG), located into the north eastern part of the Jamaica, has the highest capacity in Jamaica and it is more than 50% of total capacity. Moreover, its capacity was calculated by ministry of energy, mining and telecommunication of Jamaica and recorded as 50.5Mw out of totally 93.9 MW capacities.

Solar

Jamaica has a good potential of solar energy depending on its location and tropical weather conditions. Moreover, Jamaica on average has 7-9 hours sunshine per day and the intensity of solar irradiation was recorded as almost 5kWh/m^2/day. The implementation of weather is perfectly suited for this small island country and the rising the price of oil and the cost of the generation of electricity, encourages the authority to implement solar system. The potential of the solar energy mostly seen on the south part of the island where is suitable for implementation of the systems.

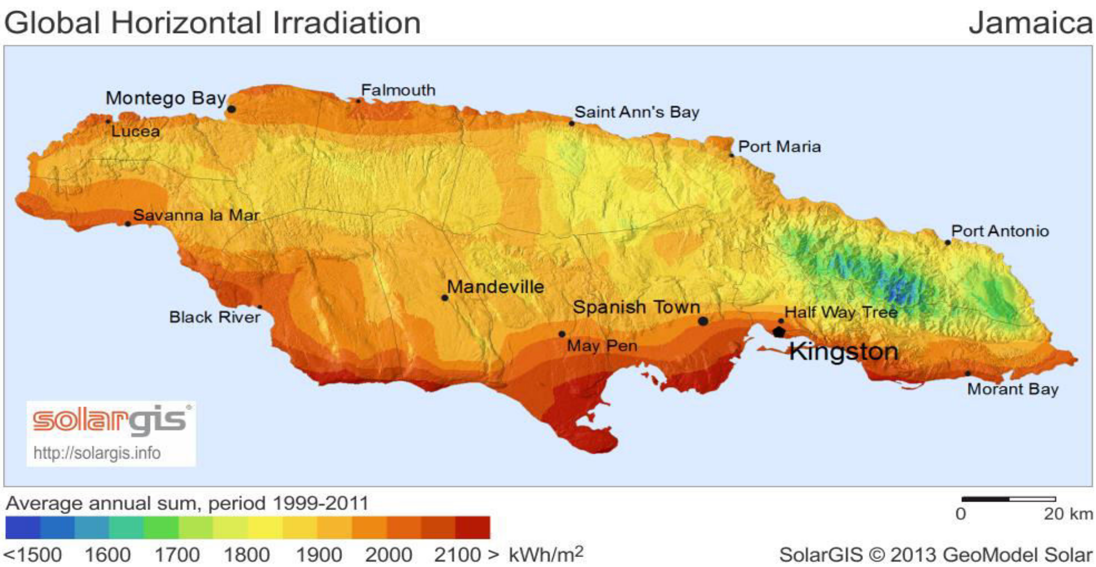

Figure 15. Solar Irradiation Map of Jamaica
Source:http://solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Jamaica-en.png

Biomass

Biomass sector in Jamaica is recently built up. It is mostly depending on the sugarcane bagasse. However, the production of sugar cane is limited because of the scarcity of the land availability. Therefore, Jamaicans produces and uses sugarcane bagasses as the coal in order to produce an energy for providing sustainable energy to the rural areas. Moreover sugarcane bagasses have the highest share of usage in biomass sector and pursued by the fuel-wood elephant grasses, agro-forestry, and bamboo etc. Depending on these resources, the electricity generations are connected to the grid and providing electricity to the nation.

3.5 Dominican Republic

Energy sector, in Dominican Republic, depends to the traditional generations and works with high electricity costs, problems on distribution, poor infrastructure; destroying nature etc. and the country is now generally accept to implement renewable energy systems as an alternative energy systems in order to generate sustainable energy to the people. There is ongoing development in electricity generation by renewable. Therefore, energy sector dependence to fossil fuels was counted as approximately 90.5% while almost 67% of the country has an access to the electricity. The electricity generation of Dominican Republic mostly belongs to the stream turbines, gas turbines, diesel turbines and also some portion of it is produced by hydroelectricity and wind. Total electricity consumption per capita was recorded by World Bank in 2011 as 893.31 kWh per year while peak demand was measured as 2168 MW in a year. By 2028, it is estimated to reach more than 4400MW and net generation rising to almost 23,7500GWh where 3.4% was estimated as rising rate per year. (Caribbean Regional Electricity Generation, Interconnection, and Fuels Supply Strategy, 2010) Moreover, this dependence on oil for electricity production blocks economic growth of the county. Hernandez(2012) mentioned that, oil dependence of electricity, low investment, low level of management, electricity theft, high operating costs, low bill collection, high electricity prices, are such factors for which cause preventing the economic growth of the country.

Depending on this issue, the authority of Dominican Republic, similar to other Latin American states, tries to establish reforms for its electricity sector in order to solve the difficulties belongs to the higher rate of operation costs, inefficiency in management and higher dependence on oil using for electricity generation. Additionally, government enacted a law and tries to encourage the investment on renewable energy in order to provide sustainable electricity for rural area and other regions and targeted to reach 25% share of renewable energy generation in total energy by 2025. Nowadays, Dominican Republic mostly invests on the hydropower and wind potentials. But it invests to the solar photovoltaic system at a lower rate than the Hydropower and Wind energy systems.

Hydropower potential has the highest share in total energy consumption and followed by wind. Moreover, solar energy takes at a lower rate of share in total energy consumption while it is newly established in Dominican Republic. Numerically, according to Renewable Facts, hydropower takes 93% of total renewable installed capacity, while wind installation is recorded as 5.4% and biomass 1.6%. On the other hand, when the shares are focused in total electricity generation, 89.4% is conventional, almost 10% is Hydro and 0.7% was recorded as other renewable.

Solar

On average daily sunshine of the country was measured as 6,34kWh/m^2/day. Also the potential reaches almost 1000 kWh/m^2/yr which is almost equal to 100 liter of oil per square meter. Ochs et al. (2011) mentioned that the highest potential in Dominican Republic is measured in 2 region where named as Santo Domingo and Santiago. Both regions' potentials are mentioned as very strong potentials compared to other nations potential. Santo Domingo potential was counted as 5.45kWh/m^2/day. Additionally Santiago has the same characteristics and its potential was recorded as 5.60kWh/m^2/day. In Dominican Republic, solar energy has the high potential and slowly become a crucial sector. This potential will help Dominican Republic in order to have low cost for generation, stabilization in voltage events, reduce pollution etc. However, the implementation rate is still low while the authority highly subsidizes it.

The reason for this is the high costs of implementation while many people şn the country living less than the poverty line. Hence, in 2009, the first solar farm was installed in the country with 20 Mw capacities and planned to implement 200 to 500 Kw projects on rooftops and on the ground. (Zanon and Boylan, 2013)

Wind

Dominican Republic wind potential is very suitable for the country in order to invest and generate electricity for people who cannot reach sustainable energy and have no access to grid. In many regions the wind potential speed was measured as more than 7 m/s at 80 meter higher than the level of sea. Ochs et al. (2011) mentioned that wind speed n 13% of the regions have 7 m/s or more than that speed. The higher and a good potential, which is sustainable and suitable to implement the system, is placed in the western part of the country. However, it is also mentioned that the seasons are the main factor that affects negatively for the sustainable generation by wind potential.

Therefore, in the country, the government was implemented two important wind farms which are named as Juacho Los Cocos and Quilvio Cabrera with a total capacity of 33 Mw and targeted to install more and reach to 75 Mw. Also, the authority planned to start operation by 2 new wind farms Matafongo and El Guanillo with total capacity of 80 Mw.

Hydropower

Dominican Republic has the more potential of hydropower than other countries which placed in Caribbean region. Besides, it is known as main suitable resource of energy and extremely suitable to capture wastes of energy. The electricity production by hydropower was measured and mentioned in World Bank records as between 10% and 15% of total electricity production of Dominican Republic.

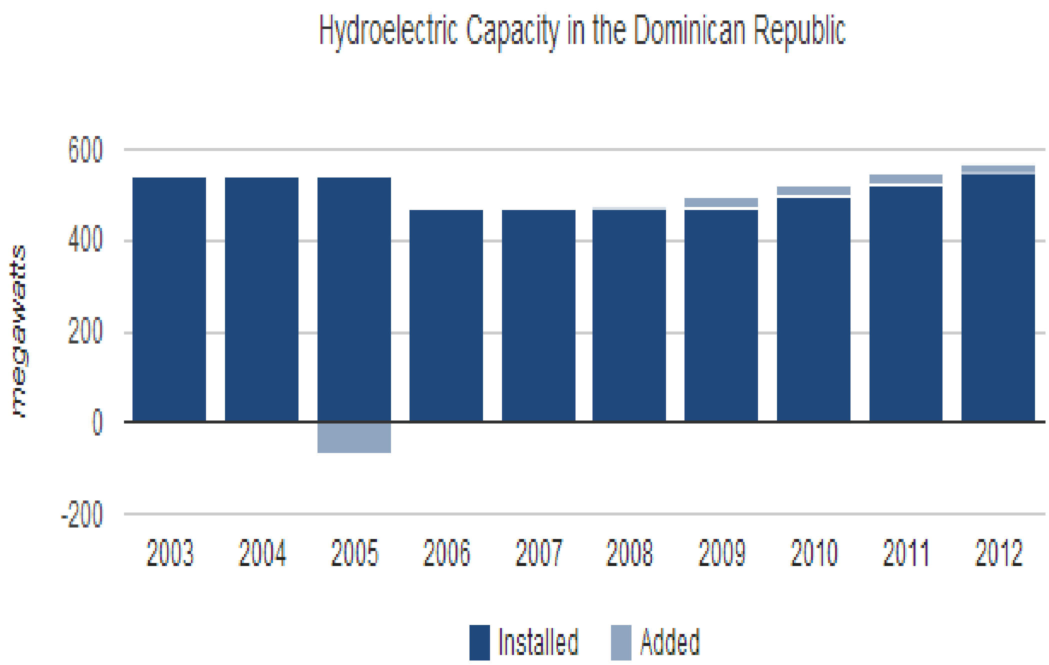

Figure 16: Hydropower capacity in Dominican Republic
Source: http://www.renewablefacts.com/country/dominican-republic/hydro

Compared to other renewable energies, Dominican Republic generates its electricity mostly from hydropower with an installed capacity of 570 Mw. The share of hydropower as a percentage of total electricity generation is 9.82% while the share of total renewable capacity in generation was approximately 93%.

Biomass

Biomass potential is not much in Dominican Republic depending on the geographical difficulties of collecting wastes such as limited agricultural wastes and municipal wastes etc. The biomass resources in Dominican Republic can be listed as: rice husks, coconut shells, sawdust, and wood chips.

3.6 Singapore

Singapore is a small island in terms of the land size, which is very crowded by population per km^2. Depending on increasing rate of population, energy needs are increasing day by day. The more demand for the energy, the more interest that the government has to show. Energy in Singapore like other countries in the world become a crucial sector and mostly considered sector for sustainable growth and development. Moreover, According to World Bank (2011), total importation value of the oil from other countries was measured as almost 98% while 100% of the people have an access to electricity. Additionally, with an increasing rate of demand for electricity, per capita consumption was recorded as 8,404.23 kWh where the peak demand was around 650 MW.

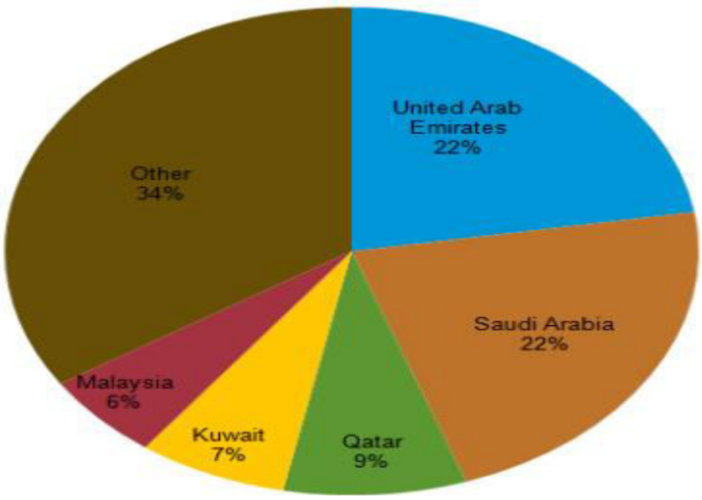

Figure 17: Singapore Crude oil imports by Source, 2012
Source: EIA, 2012

Singapore mostly imports crude oil from United Arab Emirates, Saudi Arabia, and Qatar which takes the share above 50% of its net import. Additionally, they followed by Kuwait, Malaysia by 7% and 6% respectively.

Depending on this issue, the government wants to provide the sustainable voltage with invest on alternative energies with developing technologies. Solar energy and biomass energy hold as the best opportunities for Singapore to invest where there is no other suitable alternative resource. According to Green energy plan of Singapore, in 2009, sustainable Singapore Blueprint Cooperation declared that the aim is to reduce power intensity by 35% by 2030 from a level of 2005.

Solar

Singapore has on average 5.6 hours daily sunshine and the 1,150kWh/m2/year total solar irradiation. However, there is no official data for renewable energy generation due to small size of the island country and low alternative resources for energy generation. Also,in order to produce sustainable energy, solar energy was shown as the most suitable alternative source (Jacobs and Savacool, 2010). solar energy system mostly used for water heating in Singapore and mostly implemented by hotels and large scale catering facilities. Therefore, its implementation in Singapore economy is still more costly. Singapore authority tries to implement PV projects for providing sustainable electricity to state grid and satisfy the peak demand supporting with solar PV alternative. According to REN21, in 2012, Singapore became the largest solar cooling system home compared to other states. It was using almost 4000 area for collectors with the capacity of 2,7 Mw. By 2012, 120 solar PV systems were installed and connected to grid with a capacity of 5.26 MW in order to overcome the scarcity of electricity and the largest solar PV farm was installed to the country. (IEA, 2013)

Hydropower

Singapore does not have efficient level of hydropower potential depending on the limitations of the geography and weather conditions.

Biomass

Biomass sources are one of the implemented renewable energy potential after solar systems. Singapore has been using wood horticultural wastes, municipal solid wastes for large scale of energy generations. Moreover, biomass energy production is limited in the country and has 220 mw capacities of wood wastes. There are two established companies named that M/S Eco-IEE Pte Ltd. and M/S Bee Joo Industries Pte Ltd. with the capacity of 0,53Mw and 1Mw. They both tries to get biogass and composed materials using food and other wastes like horticultural wastes and municipal solid wastes.

Wind

Wind potential is too low and depends on the season in Singapore. However, besides to this, there is an implementation for this alternative resource with lower capacity of systems. On average wind speed was measured as 2-3 m/s and tried to utilize from it. The plot projects are implementing to the suitable regions and tried to contribute the energy grids by using it. However, the electricity generation by wind potential is still weak.

Chapter 4

METHODOLOGY

4.1 Multi-Criteria Decision Making Method

By using qualitative and quantitative data, Multi-criteria decision making method (MCDM) tries to solve the dilemma. It creates choices among alternatives with respect to the specific targets and measurable criteria. This method is mostly used in research fields for selecting the best for dilemma, which involves arguments and multiple targets. (Ishizaka and Labib, 2011)

However, it is well known that, the more incompatible the targets are, the more complex the problems. Besides, compatible objectives lead to difficulties in making decisions. In selecting the best opportunity, MCDM method can be used for ranking and regulating the alternatives order from the most preferable to the least preferable. Hence, based on uncertain conditions, MCDM method is used by the researcher to make suitable decisions about the most appropriate choice (Cheng, 2000)

Saaty (1980) recommended that there are some sub-methods under the MCDM method which can be used to analyze complex problems. Among the sub-methods, Analytical Hierarchy Process (AHP) happens to be the most used and best known method in analyzing situations and problems that contains multiple and controversial targets. This technique helps authors to comprehensively analyze the situation and also structure the decision problem.

In this work, Analytical Hierarchy Process method is used for evaluating the appropriate renewable energy potentials used for electricity generation in selected small island countries. Additionally, in order to reach this goal five major criteria's were provided to make an unsuspicious decision to policy makers and presented as technical, social, environmental, location and cost. Moreover, sub-criteria were set for each criterion and used for certain decisions on ranking renewable energy sources. For technical perspective, equipment design and complexity, plant design, equipment and parts availability, plant safety, training requirement and maintainability were set as a sub-criteria, for environmental issue, ecosystem and noise were taken under consideration for social issue public acceptance with quality of life and job creation also set for the location flexibility and the plant size were evaluated as a sub-criteria with the cost criteria analyzed without any sub-criteria. Thus Eigen vector was used as a method for this study as a way of evaluating AHP model.

These criteria and the sub-criteria are strengthened by the past publications. D.J Lee and J. Hwang (2010) & S.K. Lee, G. Mogi, and J.W. Kim (2008) & H. Aras, S. Erdogmus, and E. Koc were using the AHP model as methodology and used only technical and economical aspects as criteria. Therefore, by using the AHP model, environmental criteria were also added to technical and economic perspectives for achieving different goals by N .H Afgan and M.G Carvalho (2002) & K. Nigim, N. Muner, J. Green (2004) & S. K. Lee, Y. J. Yoon and J. W. Kim (2007) & C. Kahraman, I. Kaya and S. Cebi (2009). Additionally, Tsoutsos et al. (2009) uses more aspects as criteria in viewing the goals with different perspectives with the aim of achieving its goals by implementing AHP method as methodology by using technical, economical, environmental and social issues as criteria. Moreover, Ramanathan and Ganesh(1995) were using the AHP as methodology to appraise the allocations of the power resources for Indian household sector. Furthermore, Kablan (2004) worked on the Jordan economy and its plans for the selection of the energy preservation. Chatzimouratidis and Pilavachi (2008) also used the AHP model in comparing the effects of the renewable and non-renewable energy fuel based plant with their impacts being on life quality. Also, they used technological and economic criteria in differentiating the number of energy plants for electricity production in 2009. Chatzimouratidis and Pilavachi (2008). In addition, Theodorou et al. (2010) conducted AHP model and used the method in Cyprus Island in finding out the most appropriate financing plan for projects on renewable energy. Whereas, Amer And Daim (2011) appraised the sustainability of electricity production in Pakistan energy sector while Bas (2013) was applying the same thing for Turkish electricity generation.

The further information is given in the following section about AHP method.

4.2 Analytical Hierarchy Process (AHP)

Thomas L. Saaty investigated AHP model in 1980s. It is very useful for decision maker in order to solve the problems and rank the best alternative in order to reach best decision. Also, theoretical structure of this method was established and considered as a way of tangible and intangible points of view. Consequently, this method provides the researcher to make decisions with respect to their knowledge, experiences and perceptions. (Berittella et al., 2007)

Depending on priorities and the characteristics the dilemmas are separated in to the elements. Thus, AHP model lies on 3 dominant issues such as goal, criteria and alternatives.

Goal: Main aim of the hierarchy that the researcher tries to reach. (i.e. The goal of new worker is buying a car)

Criteria: Mid-stage of the hierarchy. There can be several criteria which are helpful to reach the goal.(i.e. There would be 4 criteria for selecting car: model, color, maximum speed, fuel consumption.)

Alternatives: The last stage of the hierarchy, there can be group of alternatives for goal. (i.e. Honda, Toyota, BMW, Mercedes)

When the AHP model is shown as graphically in below Figure, each stage is represented as L_i,i= 1,2, …..t where i represents level number and t represents total. The figure below represents the aim that can be attained 4 alternatives as a way to reach goal and 4 criteria in order to evaluate alternatives.

The basic structure of the model shows the dependencies between stages with only consecutive stages of hierarchy. Also the direction of effect in hierarchy is possible only from the top stage to the end. Thus, the factors of each level are accepted as mutually exclusive (Adamcsek,2008)

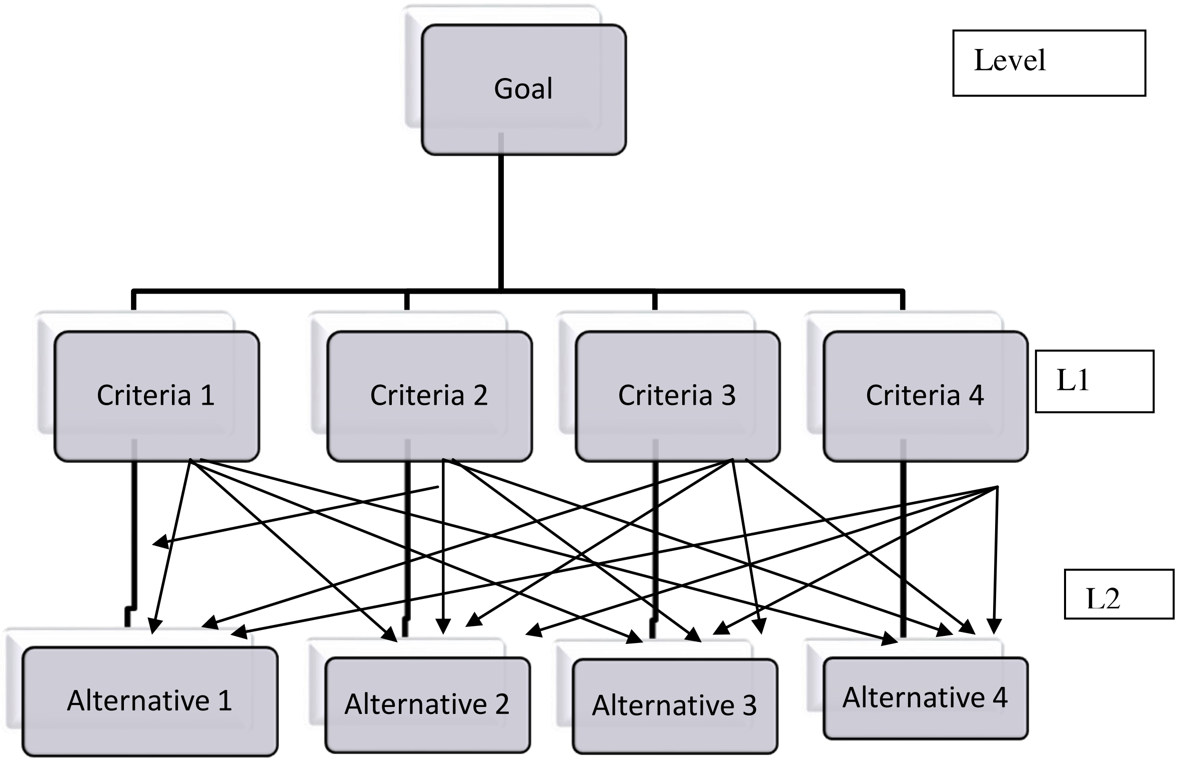

Figure 18 : Schematic representation of AHP
Source: Prepared by Author

4.3 AHP Steps

When the problem is defined by the criteria and alternatives five major steps have to be followed in order to reach the unsuspicious result and making the exact decision.

1- Develop structure of the hierarchy

2- Make Pair-wise Comparison and compare factors on hierarchy

3- Derive priority vector

4- Calculate consistency of the predilection

5- Get the alternatives' comprehensive priorities

In the model, precedence shows the importance level of the factors in hierarchy among each other and those are used to the alternative which are related with the goal.

4.3.1 Structuring the Hierarchy

It belongs to the number of stages of the hierarchy involvement of dilemma and detailed requirement for the problem. There are many AHP models are used for describing the dilemma for goal. Some of them can be listed as: (Dyer and Forman, 1991)

- Goal, Criteria, Alternative
- Goal, Criteria, Sub-Criteria, Alternatives
- Goal, Criteria, Sub-Criteria, Scenarios, Alternatives
- Goal, Actors, Criteria, Alternatives
- Goal, Actors, Criteria, Sub-Criteria, Alternative

4.3.2 Pair-wise Comparison

Pair-wise comparisons are used to rank the criteria and alternatives or sub-criteria for policy makers. Firstly, the priority of the criteria has to be specified by the pair wise comparison. Secondly depending on each criterion same process gas to be done for the alternatives and finally, this comparison has to be represented in a matrix form. Thus, when the pair wise comparison matrix is prepared the listed crucial procedure has to be taken into the consideration. (Saaty, 1990)

- Matrix has to be formed by same number of elements
- Matrix must cover all feasible pair wise combinations
- Pair-wise comparison has to be used for all stages

- Square Matrix must be constituted

Saaty (1980) offered to use the scale from one to nine as a measurement and eigenvector approach. However, Kocaoglu (1983) supported to use constant-sum approach using 100 points for each level. Gerdsri (2009) compared two methods and conclude that Kocaoglu's approach is better than the Saaty approach. Then he also expressed the reason as the ranking scale from one to nine is very hard for authors and they do not need to limit their judgments with these numbers.

As the hierarchy given as a schematic explanation in figure above, for the first stage, only one matrix is occur and can be represented as:

M_1 =

	C=1	C=2	C=3	C=4
C=1	A_{11}	A_{21}	A_{31}	A_{41}
C=2	A_{12}	A_{22}	A_{32}	A_{42}
C=3	A_{13}	A_{23}	A_{33}	A_{43}
C=4	A_{14}	A_{24}	A_{34}	A_{44}

For the second stage, L2, there are four matrices and represented as same above but named differently such as M2,1, M2,2, M2,3 etc. where Aij represents the relative importance of i depending on j. Therefore the same matrices must be established by the following hierarchy levels like sub-criteria, alternatives and they have to be square matrices.

When the square matrices are needed to prepared, the priorities has to be considered and both qualitative and quantitative evaluations have to be done. Several comparison scales were offered by many researchers in the literature. For instance, Saaty (1990) established the scale for applying AHP model. This study also offered that the scale is suitable for both qualitative and quantitative researches. Moreover, the author mentioned the importance levels as follows:

Equally priority: 1

Moderate: 3

Strongly priority: 5

Very strongly priority: 7

Extremely priority: 9

Also mid-values such as 2,4,6,8 indicate the medium levels of the scales.

4.3.3 Determining the Priorities

Priorities of the elements in each matrix are explained as the level of importance with respect to the other one. Eigenvector method was offered in order to rank the importance levels in the AHP. Saaty(1980)

Therefore, both Mean of the Row Method and Geometric Mean Method was suggested by Ishizaka and Labib in 2011. Moreover they suggested that GMM can be used instead of the eigenvector approach.

Mean of Row Method: Each number in each column is divided into the sum of the column and accordingly each element is normalized. After that, arithmetic mean is calculated for the row for obtaining the priority vector.

Geometric mean method: First of all, Geometric mean is calculated for each row. Then, a vector for geometric mean should be obtained. After that, the vector, which is normalized, uses the total number of geometric mean units in order to get the priority vector.

4.3.4 Preferences Consistency

When the priorities are obtained for the elements, consistency of the results has to be evaluated. However, AHP model gives opportunities for inconsistency results. For measuring the priorities, Saaty(1980) established the ratio for consistency, CR. And the evaluation values are developed. While the consistency ratio is less than 10%, the answers are recognized and noted as a consisted and the study can be continue. However, whether if the consistency ratio is higher than the 10%, it is assumed as unacceptable level and the process has to be repeated by the researcher. Moreover its calculation can be represented as the following equation:

$$CR = \frac{CI}{RI}$$

In the equation above, CI indicates the consistency index and RI is an indicator of random index.

In order to appraise the consistency of priorities, the eigenvalue of matrix has to be calculated by using: (Saaty, 1990)

$$M_1 (W_{M1}) = \lambda_{max} (Wm_1)$$

Where Wm_1 represents importance level of the vector of the components and λ_{max} represents the eigenvalue of the matrix. It is proved that when the matrix is fully consistent, then λ_{max} become an equal number for the size of matrix. After that, when the λ_{max} was obtained, then consistency index and random index values can be calculating with respect to the following formulas: (Coyle, 2004)

$$\text{Consistency index (CI)} = \frac{\lambda\text{max} - \text{n}}{n-1}$$

- n represents the size of the matrix.

Random index values for different sizes of the matrices are given in below table.(Saaty,1977)

Table 7: RI values for different sizes of a matrix, n

Size of matrix (n)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Random Index Values	**0.00**	**0.00**	**0.58**	**0.90**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.49**

4.3.5 Alternatives' Comprehensive Priorities

This is the last stage of the Analytical Hierarchy Process that is calculated for stated targets. In order to calculate it importance level of the alternative related to the corresponding upper level component are used. For the structure of the Analytical Hierarchy Process with an aim, n criteria, and m sub-criteria, the comprehensive importance level of the alternative can be calculated with using the following formula (Ishizaka and Labib, 2011):

$$Walternative\ i = \sum_{c=1}^{n} w_c \sum_{k=1}^{m} w_{c,k,i}\ x\ w_{c,k} \qquad i = 1,2,3, \dots \dots ., p$$

Where $W_{\text{alternative i}}$ represents the comprehensive importance level of the alternative i. moreover, p indicates the sum of alternatives, $w_{(.)}$ is the component for priority indicated by (.).

Chapter 5

OBJECTIVE OF THE STUDY

5.1 Objectives

The objective of this work is based on choosing suitable renewable energy resources in increasing the contributions for the small island country's electricity production even though renewable energy resources have been used for different objectives. However, in this study, their contribution to the electricity will be analyzed and in selecting the most suitable alternative and rank the renewable energy potentials for this purpose, five main and thirteen sub-criteria have been selected depending on the comprehensive analysis of the literature review. Moreover, the number of renewable energies has been selected as an alternative based on the small island country's potentials from the four main resources which are solar, wind, biomass and hydropower. The AHP structure, for this work, is formulated with respect to four stages. The top stage is stated with a goal and followed by five criteria at second level. Moreover, in the third stage, the sub-criteria are mentioned and finally followed by the various green energy sources at the last level. The hierarchical representation of the model is shown in the figure below. At the alternative stage, hydropower, solar potential, biomass, and wind potentials are comprehensively analyzed in order to reach the goal of the study.

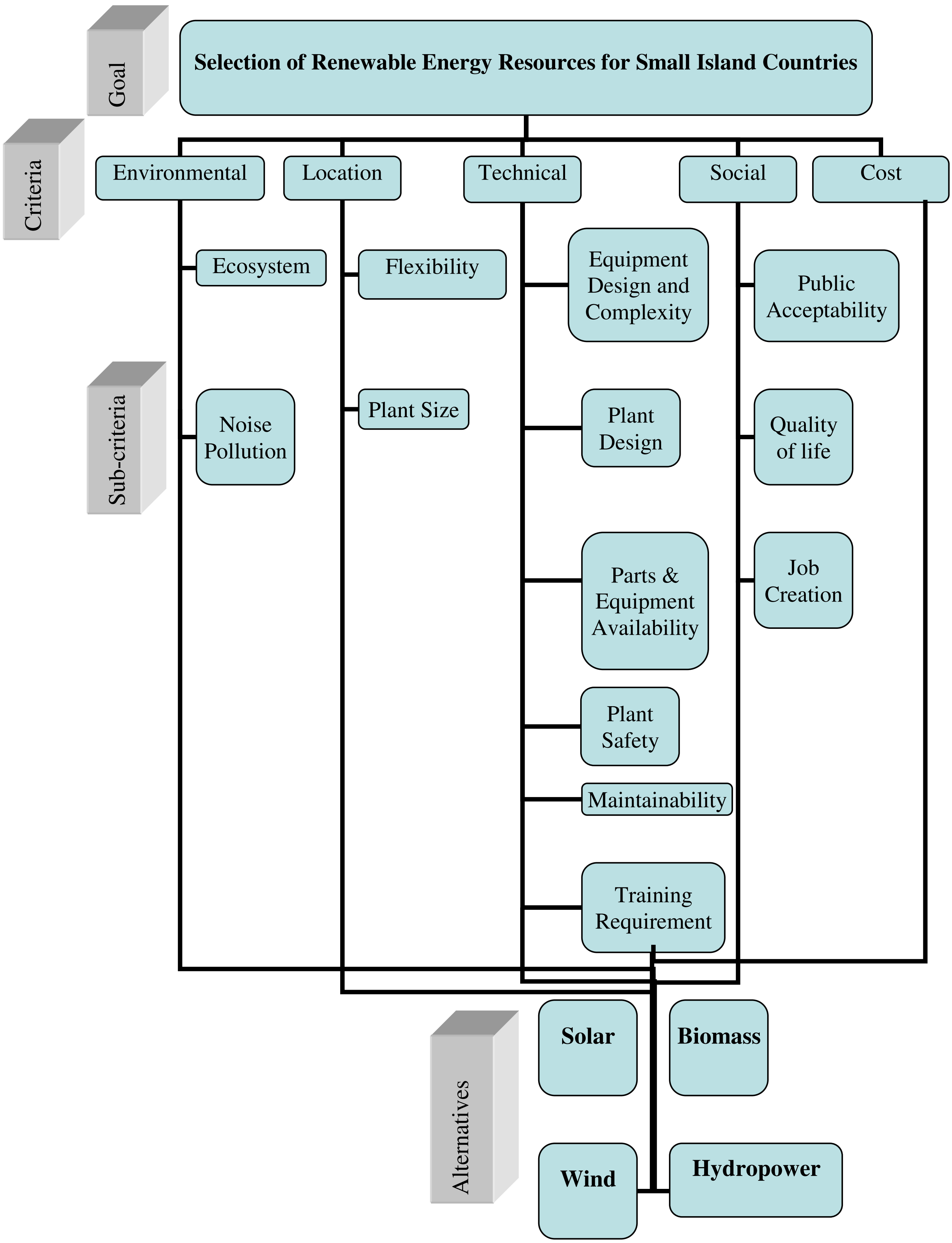

Figure 19: the proposed model of AHP
Source: Prepared by author

Table 8: Criteria and Sub-criteria used in the model

Criteria	Sub-Criteria	Description
Cost	**----------------**	Explains financial issues at a point of consumers
Social Impact	**Public Acceptability**	Evaluates people acceptance of the technology, specially biogas perspective
	Quality of life	Considers the effects on the quality of human life
	Job Creation	Consider the creation of the employment opportunities by energy project
Technical	**Equipment Design**	Implies the shape and complication of the equipment required to run the plant
	Plant Design	Considers the equipment design of the plants that can be implemented easily
	Equipment and Parts Availability	Considers the equipment whether they can be easily accessible or not
	Plant Safety	Considers the implemented technology's possibility of causing an accident
	Maintainability	Refers to the elasticity in continuity of the technology after implementation
	Training Requirement	Refers to the training that is required for continuity and operation
Location	**Flexibility**	Considers the elasticity of implementation area
	Plant Size	Capacity of the technology with respect to the distribution area
Environment	**Ecosystem**	Considers the impact on the ecosystem after implementation of the renewable energy technology
	Noise	Considers the noise pollution due to the implementation of the technology

5.2 Goals

Based on past studies, the goals of energy are set and appraised depending on countries and the well-being of the people. In this study, with respect to the aim, five main sub-criteria for the small island countries are specified. This list would be extended according the viewpoints, but, a pairwise comparison that is required by this methodology becomes difficult. However, the aim of the background and the aims represented in this work are briefly examined below.

5.2.1. Minimizing Costs

Small island countries are separated from the mainland based on geographical perspective. Thus, most of them belong to the importation of primary energy which increases the dependency of the country to the other country.

Electricity was given as one of the major economic factor for the households, industries and other sectors. Shen et al. 2011 Therefore, Electricity prices, which have the vulnerability, should be low. Low prices of electricity raise the national competitiveness and the living standards of the residents also the installations of the renewable energy technologies are low because of the implementation costs. According to that, investors prefer to implement technologies which belong to the non-renewable sources so as to generate cheaper electricity and by so earn profit.

The installation costs for the worldwide are gathered from different sources and represented in the table below:

Table 9: Investment and Energy costs of Sources

Source	Cost of Investment (dollar per kilowatt)	Energy Cost (dollar per MWH)
Solar	6,300 – 10,500	170 – 360
Wind	1,800 – 2,200	60 – 140
Geothermal	3,500 – 4,600	59 – 94
Hydropower	1,500 – 2,500	10 – 50
Biomass	1,880 – 6,800	60
Coal	1,000 – 1,500	25 – 50
Natural Gas	400 – 800	37 – 55

Source: EPA, 2012; IEA 2013; IRENA, 2012

5.2.2 Social impacts

Renewable energy technologies have some side effects on the society which might be either good or bad. The residents might be faced with some changes in their lives depending on the implemented renewable energy source.

Job Creation

Depending on past studies, it was proven that economic development and the energy are interrelated to each other. The countries which have high dependency on the importation of the energy sources like Republic of Turkey, local and the renewable energy potentials which might not only be a crucial solution for sustainable energy provision but also can create job opportunities for the people who are unemployed. (Erdal, 2012)

Investing on renewable energy contributes to the sustainability of the development of the economy, particularly through job opportunities. For instance, in 2013's UNEP publication globally, over 3.5 million people were estimated as a worker in renewable energy sector in 2010. Moreover, IRENA (2011) also mentioned that renewable energy technologies created job opportunities for people either directly or indirectly, mostly during the implementation stage, manufacturing and management periods.

The project which was newly established in the south eastern part of Turkey can be given as an example for this issue. Depending on the construction for electricity production, watering, and husbandry activities, it was aimed that the South-eastern Anatolian Project (GAP) creates 3.8 million jobs for that region. (GAP, 2011)

Table 10: Global Job creation of Renewable Energy Technologies

Types of Energy Plants	Job opportunities
Wind	630.000
Solar PV	350.000
Hydropower	N/A
Biomass	1.5 million

Source: IRENA, 2011

Quality of life

Implementation of renewable energy technologies reduces the negative effects of non-renewable energies. However, they can also have the negative effects on the nature, the habitants, and also on the peoples' health. Noise pollution, visual effects and the infected may be counted as major effects on resident's health. Those negative effects were comprehensively examined by the sources below:

Solar energy: Tsoutsos et al. (2005) mentioned that solar energy technologies which do not have coolant system can have negative effects on health and cause fire and gas loses. Moreover, like toxic wastes and abrasive liquids from the systems may have a negative effect on the health of the people. (IPCC, 2011). Additionally, the steel contained system which causes the negative effects on public health. (Meier and Steinfield, 2010)

Wind Energy: Wind power technologies cause huge noise pollutions during its operations. (EWEA, 2013) Also, Visual pollution is the other issue for public (IPPC, 2011) and the "shadow blink" while sunlight passes creates the risks for the people during the day time. (IEA, 2002).

Biomass: The collection of biomass resources and the storage of them may have negative effect on public health such as allergic reactions for the workers and the people in that region. (IPPC, 2011) Also, it may cause dust which can be a major cause of illness for the residents. (IEA, 2002)

Hydropower: Might change the quality of water, disease from water and stagnation due to implemented hydropower technologies may increase the harmful organisms that affect peoples' health. (IPPC, 2011) Also, it can be harmful for natural beauties, and environment. Moreover, noise pollution is an issue for consideration under the bad side effect of the hydropower technology implementation.

Public Acceptability

Green energy source are seen as major alternative for generating sustainable energy and the major factors for sustainable development of the country. Moreover, renewable energies, like solar and wind, contribute to the energy, environment and economy which are mentioned before.

Therefore, the public acceptances for renewable energy technologies are well identified as a major determinant for the implementation of the technologies and the accomplishment of the energy objectives. (Devine and Wright, 2007) Thus, public opposition is the biggest reason for blocking the installation of the system in that region. European Union citizens' data can be given as an example for this qualitative perspective.

Table 11: Public Opinion towards Renewable Energy Technology Implementations in European Union Countries

Types of Plants	Public opinion for technology
Wind	71%
Solar PV	80%
Solar Thermal	80%
Biomass	55%

Source: EWEA, 2009

5.2.3 Technical Issue

This criterion covers several technical and operational perspectives for the installation of the technology. It represents equipment design and complexity, plant design, equipment and parts availability, plant safety, maintainability, and lastly training requirement as sub-criteria. Those are briefly explained below:

- **Equipment Design and Complexity:** the shape and the complications of the gears are taken under consideration for this study which is needed to run the plant.
- **Training Requirement:** it is determined as the quantity of training that is needed for continuity and operation.
- **Maintainability:** it is stated as the elasticity of servicing the technology after implementation.

- **Plant Safety:** The possibility of the accident creation while the technology operation is examined in this section.
- **Plant Design:** In general, plants has many kinds of equipment but in this factor the implementation of these equipment are examined whether they are easily implemented or not.
- **Equipment and Parts Availability:** This factor is considered as a main factor under the technical criteria because availability of the tools and equipment for the plants are the affecting the residents' decisions for implementation in the country. The more easily accessible tools and equipment, the more tendencies for implementing the renewable energy technologies.

5.2.4 Location

This part is deliberated the suitable locations of the renewable energy system implementation depending on the land requirement. Thus, flexibility of the technology and plant size is selected as the sub-criteria for this aim. Those sub-criteria are briefly examined below:

- **Flexibility:** The implementation areas are examined and the suitable locations according to the potentials are evaluated.

Table 12: Land Requirement for Electricity production by RE technologies

Types of Plants	**Land Requirement (km2/ thousand MW)**
Biomass	**500**
Wind	**100**
Solar Thermal	**40**
Solar PV	**35**

Source: (Chatzimouratidis and Pilavachi , 2008; Muller-Steinhagen,2008)

- **Plant Size:** The capacity of the plant taken under consideration with respect to the distribution region. Below table shows the capacity factors of the kinds of the technologies according to US data

Table 13: Average capacity factors depending on US data.

Types of Plants	Capacity factor (%)
Biomass	**83**
Wind	**34**
Solar PV	**25**
Solar Thermal	**18**

Source: EIA,2011

5.2.5 Sustainability of Environment

Sustainability is simply identified as satisfying the present generation economic, social and environmental needs without any limitation of the future generation needs. (Morelli,2011) Though, Renewable energy is selected as a best alternative energy sources which contributes the environmental ecosystem by replacing the fossil fuels. However, the negative effects of the renewable energy resources for eco-system are separately evaluated below:

Solar Energy: Solar energy technologies may affect the animals, plants, and living environment (U.S Department of energy, 2012). Additionally, those technologies need large area which reduces the agricultural areas. (Turney and Fthenakis, 2011) Moreover, while installing the plants, it can cause gas loose and discharge of the toxic and combustible materials and water pollutions. (Tsoutsos et al., 2005)

Hydropower: Large dams may cause climate change which can also change the local temperature (IPCC, 2011). Moreover, these technologies have negative effect on habitants, land use, raise acidifying, and eutrophication. (IEA, 2002)

Wind Energy: it may have negative impact on habitants and can cause changes in the route of the migratory birds. (Karydis, 2013)

Biomass Energy: according to IPCC (2011), biomass may cause deforestation and decreasing biodiversity and soil degeneracy. Moreover, Wildlife may be affected and the regional climate may be changed depending on the biomass power plants. (IEA, 2002)

Noise Pollution: This factor considers the probability of the noise creation of the implemented technology during the operational life.

Chapter 6

ANALYSIS OF STUDY

The methodology of analytical hierarchy process was conducted for selected small island countries' renewable energy potentials in order to reach the goal and it is explained in Chapter 4. AHP procedure is followed to analyze the countries' potentials. Each renewable energy potential for country was compared with other potentials depending on the sub-criteria and the higher level of criterion and the priority levels have been determined. The analysis results are represented below for each small island country. This model consists of four stages that are stated as goal, criteria, sub-criteria and alternatives. The goal was stated on the top of the hierarchy. Selection of the best alternative energy sources is set as a goal of the decision model. Five main criteria and thirteen sub-criteria were selected in order to reach the goal and the potentials for the countries are selected as the alternatives.

6.1 Malta

For analyzing renewable energy potentials of Malta, Renewable energy technology options have been compared with each other. In other words, Malta's renewable energy potentials have been taken under consideration by using the criteria, sub-criteria, and alternatives approach and their weights have been determined. The results for the analysis are given below tables:

Table 14: Pairwise comparison matrix for the first level criteria for Malta.

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	5	2	3	5	0.438
Social	0.2	1	0.33	0.5	1	0.081
Technical	0.5	3	1	2	3	0.249
Location	0.33	2	0.5	1	2	0.149
Environment	0.2	1	0.33	0.5	1	0.081
						∑= 0.998

CR=0.003<0.1 ok.

Table 15: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Malta

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 16: Pairwise comparison matrix under Technical Criterion (sub-criteria) for Malta

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainability	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.33	2	2	2	0.153
Parts and Equipment Availability	3	3.03	1	8	5	5	0.456
Plant Safety	0.33	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	2	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.00

CR= 0.005<0.1 ok.

Table 17: Pairwise comparison matrix under Location Criterion (sub-criteria) for Malta

	Flexibility	Plant Size	Priorty Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok

Table 18: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Malta

	Ecosystem	Noise Pollution	Priorty Vector
Ecosystem	1	0,5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00 <0.10 ok

Table 19: Pairwise comparison matrix for Cost per Unit of Energy for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	2	0.558
Biomass	0.25	1	0.33	0.32
Wind	0.5	3	1	0.122
				∑= 1.00

CR= 0.016<0.1 ok.

Table 20: Pairwise comparison matrix for Public Acceptability for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	3	2	0.55
Biomass	0.333	1	1	0.21
Wind	0.5	1	1	0.24
				∑= 1.00

CR=0.016<0.10 ok.

Table 21: Pairwise comparison matrix for quality of life for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	2	1	0.367
Biomass	0.5	1	0.2	0.135
Wind	1	5	1	0.498
				∑= 1.00

CR= 0.081<0.10 ok

Table 22: Pairwise comparison matrix for Job Creation for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	1	0.458
Biomass	0.25	1	0.333	0.416
Wind	1	3	1	0.126
				∑= 1.00

CR= 0.008<0.10 ok

Table 23: Pairwise comparison matrix for Equipment Design and Complexity for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	2	3	0.54
Biomass	0.5	1	2	0.297
Wind	0.333	0.5	1	0.163
				∑= 1.00

CR=0.008<0.10 ok.

Table 24: Pairwise comparison matrix for Plant Design for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	3	0.634
Biomass	0.25	1	1	0.192
Wind	0.333	1	1	0.174
				∑= 1.00

CR= 0.008<0.10 ok.

Table 25: Pairwise comparison matrix for Equipment and Parts Availability for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	2	0.584
Biomass	0.25	1	1	0.184
Wind	0.5	1	1	0.232
				∑= 1.00

CR=0.046<0.10 ok

Table 26: Pairwise comparison matrix for Plan safety for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	1	0.458
Biomass	0.25	1	0.333	0.416
Wind	1	3	1	0.126
				∑= 1.00

CR=0.008<0.10 ok

Table 27: Pairwise comparison matrix for Maintainability for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	4	1	0.458
Biomass	0.25	1	0.333	0.126
Wind	1	3	1	0.416
				∑= 1.00

CR=0.008<0.10 ok

Table 28: Pairwise comparison matrix for Training Requirement for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	5	2	0.582
Biomass	0.2	1	0.333	0.309
Wind	0.5	3	1	0.109
				∑= 1.00

CR=0.003<0.10 ok

Table 29: Pairwise comparison matrix for Flexibility for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	0.5	6	0.348
Biomass	2	1	7	0.582
Wind	0.167	0.143	1	0.069
				∑= 0.999

CR=0.028<0.10 ok

Table 30: Pairwise comparison matrix for Plant Size for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	2	5	0.582
Biomass	0.5	1	3	0.309
Wind	0.2	0.333	1	0.109
				∑= 1.00

CR=0.003<0.10 ok

Table 31: Pairwise comparison matrix for Ecosystem for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	6	2	0.614
Biomass	0.167	1	0.5	0.268
Wind	0.5	2	1	0.117
				∑= 0.999

CR=0.016<0.10 ok

Table 32: Pairwise comparison matrix for Noise Pollution for Malta

	Solar	Biomass	Wind	Priority vector
Solar	1	1	7	0.487
Biomass	1	1	5	0.435
Wind	0.143	0.2	1	0.078
				∑= 1.00

CR=0.011<0.10 ok

Table 33: (Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Malta

		Social Impact (0,081)			Technical (0,251)						Location (0,149)		Environment (0,081)		
	Cost (0.438)	PA (0.55)	QL (0.24)	JC (0.21)	EDC (0.164)	PD (0.153)	PEA (0.456)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.558	0.55	0.367	0.458	0.54	0.634	0.584	0.458	0.458	0.582	0.348	0.582	0.614	0.487	0.524

Wind	0.32	0.24	0.498	0.416	0.163	0.192	0.232	0.416	0.416	0.309	0.069	0.109	0.268	0.078	0.257
Biomass	0.122	0.21	0.135	0.126	0.297	0.174	0.184	0.126	0.126	0.109	0.582	0.309	0.117	0.435	0.219

The above table shows the overall priority vector and proves that Malta's most appropriate option for reaching this objective is solar energy. This means that solar energy is the most suitable energy resource for Malta in order to supply its energy sustainably and have a sustainable economic growth. Moreover, this resource is followed by wind and biomass respectively.

6.2 Cyprus

Table 34: Pairwise comparison matrix for the first level criteria for Cyprus

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	0.2	0.5	0.333	0.2	0.061
Social	5	1	2	2	0.5	0.266
Technical	2	0.5	1	0.5	0.333	0.115
Location	3	0.5	2	1	0.5	0.18
Environment	5	2	3	2	1	0.378
						∑= 1.00

CR=0.017<0.10 ok.

Table 35: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Cyprus

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 36: Pairwise comparison matrix under Technical Criterion (sub-criteria) for Cyprus

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainability	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.333	2	2	2	0.153
Parts and Equipment Availability	3.03	3.03	1	8	5	5	0.457
Plant Safety	0.333	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	2	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.00

CR= 0.005<0.10 ok.

Table 37: Pairwise comparison matrix under Location Criterion (sub-criteria) for Cyprus

	Flexibility	Plant Size	Priorty Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok

Table 38: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Cyprus

	Ecosystem	Noise Pollution	Priorty Vector
Ecosystem	1	0.5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00 <0.10 ok

Table 39: Pairwise comparison matrix for Cost per Unit of Energy for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	3	5	0.648
Biomass	0.333	1	2	0.23
Wind	0.2	0.5	1	0.122
				∑= 1.00

CR= 0.003<0.10 ok.

Table 40: Pairwise comparison matrix for Public Acceptability for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	3	0.54
Biomass	0.5	1	2	0.297
Wind	0.33	0.33	1	0.163
				∑= 1.00

CR=0.008<0.10 ok.

Table 41: Pairwise comparison matrix for quality of life for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	1	0.367
Biomass	0.5	1	0.2	0.135
Wind	1	5	1	0.498
				∑= 1.00

CR= 0.081<0.10 ok

Table 42: Pairwise comparison matrix for Job Creation for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	1	2	0.387
Biomass	1	1	3	0.444
Wind	0.5	0.333	1	0.169
				∑= 1.00

CR= 0.016<0.10 ok

Table 43: Pairwise comparison matrix for Equipment Design and Complexity for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	5	0.582
Biomass	0.5	1	3	0.309
Wind	0.2	0.333	1	0.109
				∑= 1.00

CR=0.003<0.10 ok.

Table 44: Pairwise comparison matrix for Plant Design for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	4	0.558
Biomass	0.5	1	3	0.32
Wind	0.25	0.333	1	0.122
				∑= 1.00

CR= 0.016<0.10 ok.

Table 45: Pairwise comparison matrix for Equipment and Parts Availability for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	4	0.558
Biomass	0.5	1	3	0.32
Wind	0.25	0.333	1	0.122
				∑= 1.00

CR=0.016<0.10 ok

Table 46: Pairwise comparison matrix for Plant safety for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	0.25	1	0.174
Biomass	4	1	3	0.634
Wind	1	0.333	1	0.192
				∑= 1.00

CR=0.008<0.10 ok

Table 47: Pairwise comparison matrix for Maintainability for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	3	2	0.528
Biomass	0.333	1	0.333	0.14
Wind	0.5	3	1	0.333
				∑= 1.00

CR=0.046<0.10 ok

Table 48: Pairwise comparison matrix for Training Requirement for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	5	0.582
Biomass	0.5	1	3	0.309
Wind	0.2	0.333	1	0.109
				∑= 1.00

CR=0.003<0.10 ok

Table 49: Pairwise comparison matrix for Flexibility for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	0.5	6	0.348
Biomass	2	1	7	0.582
Wind	0.167	0.143	1	0.069
				∑= 0.999

CR=0.028<0.10 ok

Table 50: Pairwise comparison matrix for Plant Size for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	2	5	0.582
Biomass	0.5	1	3	0.309
Wind	0.2	0.333	1	0.109
				∑= 1.00

CR=0.003<0.10 ok

Table 51: Pairwise comparison matrix for Ecosystem for Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	6	2	0.614
Biomass	0.167	1	0.5	0.268
Wind	0.5	2	1	0.117
				∑= 0.999

CR=0.016<0.10 ok

Table 52: Pairwise comparison matrix for Noise Pollution For Cyprus

	Solar	Biomass	Wind	Priority vector
Solar	1	1	7	0.487
Biomass	1	1	5	0.435
Wind	0.143	0.2	1	0.078
				∑= 1.00

CR=0.011<0.10 ok

Table 53:(Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Cyprus

		Social Impact (0.266)			Technical (0.115)						Location (0.18)		Environment (0.378)		
	Cost (0.061)	PA (0.26)	QL (0.327)	JC (0.413)	EDC (0.164)	PD (0.153)	PEA (0.457)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.648	0.45	0.367	0.387	0.582	0.558	0.558	0.174	0.528	0.582	0.348	0.582	0.614	0.487	0.483
Wind	0.122	0.163	0.498	0.169	0.109	0.122	0.122	0.192	0.333	0.109	0.069	0.109	0.268	0.078	0.164
Biomass	0.230	0.297	0.135	0.444	0.309	0.320	0.320	0.634	0.140	0.309	0.582	0.309	0.117	0.435	0.353

The above table shows the overall priority vector and proves that Cyprus's most suitable option for reaching objective of the study is solar energy. Solar energy potential's priority is measured as 0.483 and ranked as first suitable alternative energy resource for generating electricity and it is followed by biomass and wind energy with a priority level of 0.353 and 0.164 respectively. This means that investing on the solar energy is the most beneficial alternative energy resource for reaching the sustainable economic growth and providing satisfied energy to the citizens of Cyprus.

6.3 CUBA

Table 54: Pairwise comparison matrix for the first level criteria for Cuba

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	0.2	0.5	0.333	0.2	0.061
Social	5	1	2	2	0.5	0.266
Technical	2	0.5	1	0.5	0.333	0.115
Location	3	0.5	2	1	0.5	0.180
Environment	5	2	3	2	1	0.378
						∑= 1.00

CR=0.017<0.10 ok.

Table 55: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Cuba

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 56:Pairwise comparison matrix under Technical Criterion(sub-criteria)forCuba

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainability	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.333	2	2	2	0.153
Parts and Equipment Availability	3.03	3.03	1	8	5	5	0.457
Plant Safety	0.333	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	2	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.01

CR= 0.005<0.10 ok.

Table 57: Pairwise comparison matrix under Location Criterion (sub-criteria) for Cuba

	Flexibility	Plant Size	Priorty Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok.

Table 58: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Cuba

	Ecosystem	Noise Pollution	Priorty Vector
Ecosystem	1	0.5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00 <0.10 ok

Table 59: Pairwise comparison matrix for Cost per Unit of Energy for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	3	5	8	0.602
Biomass	0.333	1	2	2	0.198
Wind	0.2	0.5	1	2	0.123
Hydropower	0.125	0.5	0.5	1	0.078
					∑= 1.00

CR= 0.015<0.10 ok.

Table 60: Pairwise comparison matrix for Public Acceptability for Cuba

	Solar	Biomass	Wind	Hdropower	Priority vector
Solar	1	2	3	9	0.519
Biomass	0.5	1	0.5	3	0.179
Wind	0.33	2	1	4	0.245
Hdropower	0.111	0.333	0.25	1	0.058
					∑= 1.00

CR=0.038<0.10 ok.

Table 61: Pairwise comparison matrix for quality of life for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	1	6	0.365
Biomass	0.5	1	0.2	2	0.134
Wind	1	5	1	4	0.426
Hydropower	0.167	0.5	0.25	1	0.075
					∑= 1.00

CR= 0.047<0.10 ok

Table 62: Pairwise comparison matrix for Job Creation for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	1	0.5	0.211
Biomass	0.5	1	0.333	0.25	0.097
Wind	1	3	1	0.333	0.216
Hydropower	2	4	3	1	0.476
					∑= 1.00

CR= 0.023<0.10 ok

Table 63: Pairwise comparison matrix for Equipment Design and Complexity for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	5	5	0.526
Biomass	0.5	1	3	2	0.262
Wind	0.2	0.333	1	1	0.101
Hydropower	0.2	0.5	1	1	0.112
					∑= 1.00

CR=0.006<0.10 ok.

Table 64: Pairwise comparison matrix for Plant Design for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	4	1	0.368
Biomass	0.5	1	3	1	0.243
Wind	0.25	0.333	1	0.25	0.082
Hydropower	1	1	4	1	0.308
					∑= 1.00

CR= 0.017<0.10 ok.

Table 65: Pairwise comparison matrix for Equipment and Parts Availability Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	4	6	0.491
Biomass	0.5	1	3	6	0.32
Wind	0.25	0.333	1	3	0.131
Hydropower	0.167	0.167	0.333	1	0.058
					∑= 1.00

CR=0.03<0.10 ok

Table 66: Pairwise comparison matrix for Plan safety for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	0.25	1	6	0.191
Biomass	4	1	3	8	0.555
Wind	1	0.333	1	7	0.212
Hydropower	0.167	0.125	0.143	1	0.042
					∑= 1.00

CR=0.053<0.10 ok

Table 67: Pairwise comparison matrix for Maintainability Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	3	2	6	0.482
Biomass	0.333	1	0.333	2	0.135
Wind	0.5	3	1	4	0.309
Hydropower	0.167	0.5	0.25	1	0.074
					∑= 1.00

CR=0.017<0.10 ok

Table 68: Pairwise comparison matrix for Training Requirement Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	5	8	0.53
Biomass	0.5	1	3	6	0.307
Wind	0.2	0.333	1	2	0.106
Hydropower	0.25	0.167	0.5	1	0.057
					∑= 1.00

CR=0.006<0.10 ok

Table 69: Pairwise comparison matrix for Flexibility for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	0.5	6	8	0.527
Biomass	2	1	7	9	0.349
Wind	0.167	0.143	1	3	0.082
Hydropower	0.125	0.111	0.333	1	0.042
					∑= 1.00

CR=0.047<0.10 ok

Table 70: Pairwise comparison matrix for Plant Size for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	5	5	0.548
Biomass	0.5	1	3	3	0.267
Wind	0.2	0.333	1	3	0.123
Hydropower	0.2	0.333	0.333	1	0.061
					∑= 0.999

CR=0.059<0.10 ok

Table 71: Pairwise comparison matrix for Ecosystem for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	6	2	9	0.559
Biomass	0.167	1	0.5	4	0.149
Wind	0.5	2	1	6	0.249
Hydropower	0.111	0.25	0.167	1	0.043
					∑= 1.00

CR=0.03<0.10 ok

Table 72 : Pairwise comparison matrix for Noise Pollution for Cuba

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	1	7	9	0.462
Biomass	1	1	5	8	0.41
Wind	0.143	0.2	1	2	0.08
Hydropower	0.111	0.125	0.5	1	0.047
					∑= 0.999

CR=0.009<0.10 ok

Table 73: (Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Cuba

		Social Impact (0.266)			Technical (0.115)						Location (0.18)		Environment (0.378)		
	Cost (0.061)	PA (0.26)	QL (0.327)	JC (0.413)	EDC (0.164)	PD (0.153)	PEA (0.457)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.602	0.519	0.365	0.211	0.526	0.368	0.491	0.191	0.482	0.53	0.349	0.51	0.559	0.462	0.435
Wind	0.123	0.245	0.426	0.216	0.101	0.082	0.131	0.212	0.309	0.106	0.082	0.134	0.264	0.08	0.171
Biomass	0.198	0.179	0.134	0.097	0.262	0.243	0.32	0.555	0.135	0.307	0.527	0.28	0.132	0.41	0.289
Hydro	0.078	0.058	0.075	0.476	0.112	0.308	0.058	0.042	0.074	0.057	0.042	0.076	0.045	0.047	0.106

The above table shows the empirical results of AHP model for Cuban alternative renewable energy resources and it represents that depending on the criteria and sub-criteria evaluation solar energy became the most appropriate alternative energy in order to invest and provide energy to the grid with an efficient level and have a sustainable economic growth. Its priority level was measured as 0.435 and ranked as the most appropriate alternative renewable energy out of 4 alternatives and followed by Biomass (0.289), wind (0.171) and Hydropower (0.106) respectively.

6.4 Jamaica

Table 74: Pairwise comparison matrix for the first level criteria Jamaica

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	0.2	0.5	0.333	0.2	0.061
Social	5	1	2	2	0.5	0.266
Technical	2	0.5	1	0.5	0.333	0.115
Location	3	0.5	2	1	0.5	0.18
Environment	5	2	3	2	1	0.378
						∑= 1.00

CR=0.017<0.10 ok.

Table 75: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Jamaica

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 76: Pairwise comparison matrix under Technical Criterion (sub-criteria) for Jamaica

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainabilit y	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.333	2	2	2	0.153
Parts and Equipment Availability	3.03	3.03	1	8	5	5	0.457
Plant Safety	0.333	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	2	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.00

CR= 0.005<0.10 ok.

Table 77: Pairwise comparison matrix under Location Criterion (sub-criteria) for Jamaica

	Flexibility	Plant Size	Priority Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok

Table 78: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Jamaica

	Ecosystem	Noise Pollution	Priority Vector
Ecosystem	1	0.5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00 <0.10 ok

Table 79: Pairwise comparison matrix for Cost per Unit of Energy for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	3	5	8	0.602
Biomass	0.333	1	2	2	0.198
Wind	0.2	0.5	1	2	0.123
Hydropower	0.125	0.5	0.5	1	0.078
					∑= 1.00

CR= 0.015<0.10 ok.

Table 80: Pairwise comparison matrix for Public Acceptability for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	3	4	0.472
Biomass	0.5	1	0.5	2	0.256
Wind	0.33	2	1	2	0.164
Hydropower	0.25	0.5	0.5	1	0.108
					∑= 1.00

CR=0.017<0.10 ok.

Table 81: Pairwise comparison matrix for quality of life for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	1	6	0.365
Biomass	0.5	1	0.2	2	0.134
Wind	1	5	1	4	0.426
Hydropower	0.167	0.5	0.25	1	0.075
					∑= 1.00

CR= 0.047<0.10 ok

Table 82: Pairwise comparison matrix for Job Creation for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	1	0.5	0.211
Biomass	0.5	1	0.333	0.25	0.097
Wind	1	3	1	0.333	0.216
Hydropower	2	4	3	1	0.476
					∑= 1.00

CR= 0.024<0.10 ok

Table 83: Pairwise comparison matrix for Equipment Design and Complexity for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	5	5	0.526
Biomass	0.5	1	3	2	0.262
Wind	0.2	0.333	1	1	0.101
Hydropower	0.2	0.5	1	1	0.112
					∑= 1.00

CR=0.006<0.10 ok.

Table 84: Pairwise comparison matrix for Plant Design for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	4	1	0.368
Biomass	0.5	1	3	1	0.243
Wind	0.25	0.333	1	0.25	0.082
Hydropower	1	1	4	1	0.308
					∑= 1.00

CR= 0.017<0.10 ok.

Table 85: Pairwise comparison matrix for Equipment and Parts Availability for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	4	6	0.491
Biomass	0.5	1	3	6	0.32
Wind	0.25	0.333	1	3	0.131
Hydropower	0.167	0.167	0.333	1	0.058
					∑= 1.00

CR=0.03<0.10 ok

Table 86: Pairwise comparison matrix for Plant safety for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	0.25	1	6	0.191
Biomass	4	1	3	8	0.555
Wind	1	0.333	1	7	0.212
Hydropower	0.167	0.125	0.143	1	0.042
					∑= 1.00

CR=0.053<0.10 ok

Table 87: Pairwise comparison matrix for Maintainability for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	3	2	6	0.482
Biomass	0.333	1	0.333	2	0.135
Wind	0.5	3	1	4	0.309
Hydropower	0.167	0.5	0.25	1	0.074
					∑= 1.00

CR=0.017<0.10 ok

Table 88: Pairwise comparison matrix for Training Requirement for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	5	8	0.53
Biomass	0.5	1	3	6	0.307
Wind	0.2	0.333	1	2	0.106
Hydropower	0.25	0.167	0.5	1	0.057
					∑= 1.00

CR=0.006<0.10 ok

Table 89: Pairwise comparison matrix for Flexibility for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	0.5	3	2	0.257
Biomass	2	1	5	5	0.526
Wind	0.333	0.2	1	0.5	0.085
Hydropower	0.5	0.2	2	1	0.132
					∑= 1.00

CR=0.015<0.10 ok

Table 90: Pairwise comparison matrix for Plant Size for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	2	2	5	0.432
Biomass	0.5	1	0.25	2	0.144
Wind	0.5	4	1	4	0.347
Hydropower	0.2	0.5	0.25	1	0.077
					∑= 0.999

CR=0.064<0.10 ok

Table 91: Pairwise comparison matrix for Ecosystem for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	6	2	9	0.559
Biomass	0.167	1	0.5	4	0.149
Wind	0.5	2	1	6	0.249
Hydropower	0.111	0.25	0.167	1	0.043
					∑= 1.00

CR=0.03<0.10 ok

Table 92: Pairwise comparison matrix for Noise Pollution for Jamaica

	Solar	Biomass	Wind	Hydropower	Priority vector
Solar	1	1	7	9	0.462
Biomass	1	1	5	8	0.41
Wind	0.143	0.2	1	2	0.08
Hydropower	0.111	0.125	0.5	1	0.047
					∑= 0.999

CR=0.009<0.10 ok

Table 93: (Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Jamaica

		Social Impact (0.266)			Technical (0.115)						Location (0.18)		Environment (0.378)		
	Cost (0.061)	PA (0.26)	QL (0.327)	JC (0.413)	EDC (0.164)	PD (0.153)	PEA (0.457)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.602	0.472	0.547	0.211	0.526	0.368	0.491	0.191	0.482	0.53	0.257	0.432	0.559	0.462	0.431
Wind	0,123	0.164	0.265	0.216	0.101	0.082	0.131	0.212	0.309	0.106	0.085	0.347	0.264	0.08	0.158

Biomass	0.198	0.256	0.118	0.097	0.262	0.243	0.32	0.555	0.135	0.307	0.526	0.144	0.132	0.41	0.288
Hydro	0.078	0.108	0.07	0.476	0.112	0.308	0.058	0.042	0.074	0.057	0.132	0.077	0.045	0.047	0.122

Empirical results were conducted after using the AHP model for Jamaica and its potential alternative energies are evaluated. As a result, depending on the criteria and sub-criteria, it is founded that solar energy is the most suitable alternative renewable energy resource in order to reach goal and having an sustainable economic growth with priority level of 0.431 and biomass, wind and hydropower potentials follow solar energy with a priority level of 0.288, 0.158 and 0.122 respectively.

6.5 Dominican Republic

Table 94: Pairwise comparison matrix for the first level criteria for Dominican Republic

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	0.2	0.5	0.333	0.2	0.061
Social	5	1	2	2	0.5	0.266
Technical	2	0.5	1	0.5	0.333	0.115
Location	3	0.5	2	1	0.5	0.18
Environment	5	2	3	2	1	0.378
						∑= 1.00

CR=0.017<0.10 ok.

Table 95: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Dominican Republic

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 96: Pairwise comparison matrix under Technical Criterion (sub-criteria) for Dominican Republic

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainability	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.333	2	2	2	0.153
Parts and Equipment Availability	3.03	3.03	1	8	5	5	0.457
Plant Safety	0.333	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	1	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.01

CR= 0.005<0.10 ok.

Table 97: Pairwise comparison matrix under Location Criterion (sub-criteria) for Dominican Republic

	Flexibility	Plant Size	Priorty Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok

Table 98: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Dominican Republic

	Ecosystem	Noise Pollution	Priorty Vector
Ecosystem	1	0.5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00 <0.10 ok

Table 99: Pairwise comparison matrix for Cost per Unit of Energy for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	3	0.55
Wind	0.5	1	1	0.24
Hydropower	0.333	1	1	0.21
				∑= 1.00

CR= 0.016<0.10 ok.

Table 100: Pairwise comparison matrix for Public Acceptability for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	4	0.558
Wind	0.5	1	3	0.32
Hdropower	0.25	0.333	1	0.122
				∑= 1.00

CR=0.016<0.10 ok.

Table 101: Pairwise comparison matrix for quality of life for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	3	5	0.648
Wind	0.333	1	2	0.23
Hydropower	0.2	0.5	1	0.122
				∑= 1.00

CR= 0.00<0.10 ok

Table 102: Pairwise comparison matrix for Job Creation for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	4	0.547
Wind	0.5	1	4	0.345
Hydropower	0.25	0.25	1	0.109
				∑= 1.00

CR= 0.046<0.10 ok

Table 103: Pair wise comparison matrix for Equipment Design and Complexity for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	3	0.55
Wind	0.5	1	1	0.24
Hydropower	0.33	1	1	0.21
				∑= 1.00

CR=0.016<0.10 ok.

Table 104: Pairwise comparison matrix for Plant Design for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	0.5	0.311
Wind	0.5	1	0.5	0.196
Hydropower	2	2	1	0.493
				∑= 1.00

CR= 0.046<0.10 ok.

Table 105: Pairwise comparison matrix for Equipment and Parts Availability for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	3	4	0.634
Wind	0.333	1	1	0.192
Hydropower	0.25	1	1	0.174
				∑= 1.00

CR=0.008<0.10 ok

Table 106: Pairwise comparison matrix for Plan safety for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	1	4	0.458
Wind	1	1	3	0.416
Hydropower	0.25	0.333	1	0.126
				∑= 1.00

CR=0.008<0.10 ok

Table 107: Pairwise comparison matrix for Maintainability for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	3	0.54
Wind	0.5	1	2	0.297
Hydropower	0.333	0.5	1	0.163
				∑= 1.00

CR=0.008<0.10 ok

Table 108: Pairwise comparison matrix for Training Requirement for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	4	6	0.691
Wind	0.25	1	3	0.218
Hydropower	0.167	0.333	1	0.091
				∑= 1.00

CR=0.046<0.10 ok

Table 109: Pairwise comparison matrix for Flexibility for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	5	3	0.648
Wind	0.2	1	0.5	0.23
Hydropower	0.333	2	1	0.122
				∑= 1.00

CR=0.003<0.10 ok

Table 110: Pairwise comparison matrix for Plant Size for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	2	4	0.558
Wind	0.2	1	3	0.32
Hydropower	0.2	0.333	1	0.122
				∑= 1.00

CR=0.016<0.10 ok

Table 111: Pairwise comparison matrix for Ecosystem for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	1	3	0.443
Wind	1	1	2	0.387
Hydropower	0.333	0.5	1	0.169
				∑= 1.00

CR=0.016< 0.10 ok

Table 112: Pairwise comparison matrix for Noise Pollution for Dominican Republic

	Solar	Wind	Hydropower	Priority vector
Solar	1	3	4	0.625
Wind	0.333	1	2	0.238
Hydropower	0.25	0.5	1	0.136
				∑= 0.999

CR=0.016<0.10 ok

Table 113: (Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Dominican Republic

		Social Impact (0.266)			Technical (0.115)						Location (0.18)		Environment (0.378)		
	Cost (0.061)	PA (0.26)	QL (0.327)	JC (0.413)	EDC (0.164)	PD (0.153)	PEA (0.457)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.55	0.558	0.648	0.547	0.55	0.196	0.634	0.458	0.54	0.691	0.648	0.558	0.443	0.625	0.58
Wind	0.24	0.32	0.23	0.345	0.24	0.311	0.192	0.416	0.297	0.218	0.23	0.32	0.387	0.238	0.257
Hydro	0.21	0.122	0.122	0.109	0.21	0.493	0.174	0.126	0.163	0.091	0.122	0.122	0.169	0.136	0.163

The above table shows the overall priority vector and proves that Dominican Republic's most suitable option for reaching this objective is solar energy. This means that solar energy is the most suitable energy resource for Dominican Republic in order to reach the sustainability in providing energy and have a sustainable economic growth with a priority level of 0.58 and followed by wind potential as the second best alternative and the Hydropower as the third alternative with the priorities of 0.257 and 0.163 respectively. Moreover, this resource is followed by wind and hydropower respectively.

6.6 Singapore

Table 114: Pairwise comparison matrix for the first level criteria for Singapore

	Cost	Social	Technical	Location	Environment	Priority Vector
Cost	1	0.2	0.5	0.333	0.2	0.061
Social	5	1	2	2	0.5	0.266
Technical	2	0.5	1	0.5	0.333	0.115
Location	3	0.5	2	1	0.5	0.18
Environment	5	2	3	2	1	0.378
						∑= 1.00

CR=0.017<0.10 ok.

Table 115: Pairwise comparison matrix under Social Impact Criterion (sub-criteria) for Singapore

	Public Acceptability	Quality of life	Job Creation	Priority vector
Public Acceptability	1	1	0.5	0.413
Quality of life	1	1	1	0.327
Job Creation	2	1	1	0.26
				∑= 1.00

CR= 0.046 <0.10 ok.

Table 116: Pairwise comparison matrix under Technical Criterion (sub-criteria) for Singapore

	Equipment Design and Complexity	Plant Design	Parts and Equipment Availability	Plant Safety	Maintainability	Training Requirement	Priority Vector
Equipment Design and Complexity	1	1	0.333	3	2	2	0.164
Plant Design	1	1	0.333	2	2	2	0.153
Parts and Equipment Availability	3.03	3.03	1	8	5	5	0.457
Plant Safety	0.333	0.5	0.125	1	1	1	0.069
Maintainability	0.5	0.5	0.2	1	1	1	0.079
Training Requirement	0.5	0.5	0.2	1	1	1	0.079
							∑=1.01

CR= 0.005<0.10 ok.

Table 117: Pairwise comparison matrix under Location Criterion (sub-criteria) for Singapore

	Flexibility	Plant Size	Priorty Vector
Flexibility	1	5	0.833
Plant Size	0.2	1	0.167
			∑=1.00

CR=0.00 <0.10 ok

Table 118: Pairwise comparison matrix under Environment Criterion (sub-criteria) for Singapore

	Ecosystem	Noise Pollution	Priorty Vector
Ecosystem	1	0.5	0.333
Noise pollution	2	1	0.667
			∑=1.00

CR=0.00<0.10 ok

Table 119: Pairwise comparison matrix for Cost per Unit of Energy for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR= 0.00<0.10 ok.

Table 120: Pairwise comparison matrix for Public Acceptability for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00<0.10 ok.

Table 121: Pairwise comparison matrix for quality of life for Singapore

	Solar	Biomass	Priority vector
Solar	1	3	0.75
Biomass	0.333	1	0.25
			∑= 1.00

CR= 0.00<0.10 ok

Table 122: Pairwise comparison matrix for Job Creation for Singapore

	Solar	Biomass	Priority vector
Solar	1	4	0.8
Biomass	0.25	1	0.2
			∑= 1.00

CR= 0.00<0.10 ok

Table 123: Pairwise comparison matrix for Equipment Design and Complexity for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00<0.10 ok.

Table 124: Pairwise comparison matrix for Plant Design for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR= 0.00<0.10 ok.

Table 125: Pairwise comparison matrix for Equipment and Parts Availability for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00<0.10 ok

Table 126: Pairwise comparison matrix for Plant safety for Singapore

	Solar	Biomass	Priority vector
Solar	1	0.25	0.20
Biomass	4	1	0.80
			∑= 1.00

CR=0.00<0.10 ok

Table 127: Pairwise comparison matrix for Maintainability for Singapore

	Solar	Biomass	Priority vector
Solar	1	3	0.75
Biomass	0.333	1	0.25
			∑= 1.00

CR=0.00<0.10 ok

Table 128: Pairwise comparison matrix for Training Requirement for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00<0.10 ok

Table 129: Pairwise comparison matrix for Flexibility for Singapore

	Solar	Biomass	Priority vector
Solar	1	0.5	0.333
Biomass	2	1	0.667
			∑= 1.00

CR=0.00<0.10 ok

Table 130: Pairwise comparison matrix for Plant Size for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00<0.10 ok

Table 131: Pairwise comparison matrix for Ecosystem for Singapore

	Solar	Biomass	Priority vector
Solar	1	2	0.667
Biomass	0.5	1	0.333
			∑= 1.00

CR=0.00< 0.10 ok

Table 132: Pairwise comparison matrix for Noise Pollution for Singapore

	Solar	Biomass	Priority vector
Solar	1	1	0.5
Biomass	1	1	0.5
			∑= 1.00

CR=0.016<0.10 ok

Table 133: (Final Result) Priority Matrix for Selecting Appropriate Renewable Energy Source in order to invest for Singapore

		Social Impact (0.266)			Technical (0.115)						Location (0.18)		Environment (0.378)		
	Cost (0.061)	PA (0.26)	QL (0.327)	JC (0.413)	EDC (0.164)	PD (0.153)	PEA (0.457)	PS(0.069)	M (0.079)	TR (0.079)	Flex. (0.833)	PS (0.167)	IE(0.333)	NP(0.667)	Overall Priority Vector
Solar	0.667	0.667	0.75	0.80	0.667	0.667	0.667	0.20	0.75	0.667	0.333	0.667	0.667	0.50	0.594
Biomass	0.333	0.333	0.25	0.20	0.333	0.333	0.333	0.80	0.25	0.333	0.667	0.333	0.333	0.50	0.406

There is not much suitable alternative renewable energy resource for energy sector of Singapore. There are only solar and Biomass potentials are evaluated as an important alternative energy resource which can significantly contribute the energy sector of Singapore. Therefore, depending on the AHP model, solar energy potential became the most appropriate resource to invest and reach the goals and it is followed by the biomass. The priority ratios are measured as 0.594 and 0.406 respectively.

Chapter 7

DISCUSSION AND RESULTS

7.1 Results of AHP

Energy has become a key factor for the countries' economy. However, most of them are dependent to importations of energy which cause the reduction of the economic growth rate, human development index etc.

Recently, renewable energy potentials have become crucial sources for the energy sector both in developed and developing countries in order to achieve economic efficiency, economic growth and sustainability in economic development etc. Clean energy sources, are known as environmentally friendly sources and also socially acceptable and economically viable. Those sources can be represented as solar energy, wind energy, biomass energy, geothermal energy, hydropower etc. Those sources have been concentrated by the organizations in order to provide energy with lower prices, lower costs, and lower damage to the nature. Depending on this purpose, the best alternative green power energy potential, which can mostly contribute the energy sector of the countries, are evaluated by the AHP model and applied for 6 small islands separately. Five main and thirteen sub-criteria have been focused for this goal and prioritized among themselves.

For overall result of the renewable energy potentials in order to reach goal, a matrix is formed for each level of the hierarchy and the same job is repeated for each countries. Therefore, depending on the priorities vector, which we found it by matrix, the most appropriate renewable energy potential has been decided.

7.1.1 Malta

The overall information about Maltese energy sector has been given in the previous chapters. Simply its economy has 100% dependence on importation of the petroleum and large amount of money goes out accordingly. Moreover, both governmental and non-governmental organizations try to find a solution for this situation and evaluated its alternative energy sources. The biggest step for this issue was the integration of the energy from other country, island of Sicily, Italy. Moreover, it also tries to invest on the renewable energy sources but the costs of implementation and the other factors that are examined in this study are the main contradictories for the installation.

Therefore, in this study the pairwise comparison technique has been used and all the levels in AHP hierarchy were evaluated among themselves. For the island of Malta, there are only 3 suitable renewable energy potentials has been evaluated as the alternatives and the criteria and sub-criteria were used as a factor to reach the goal. . Priorities rate relative to each criteria, sub-criteria and alternatives were given in Chapter 6 at the last part of the section 6.1.

Solar Energy: According to this analyze, results indicates that with a 0,524 weight, solar energy became the most appropriate potential to invest, in order to reach the goal of the study. This energy potential is followed by the wind (0,257) and biomass (0,219) respectively. Moreover, in Maltese island, the priorities of the main criteria can be presented as the cost factor with a weight of 0,438. It also shows that due to the financial constraints, the investors, either government or non-government, are not willing to be risk taker to invest these potentials. From the technical perspective, parts and equipment availability, and equipment design can be seen as the most crucial sub-criteria. Thus, it indicates that, those are the major constraint to invest renewable energies which does not have available parts and equipment and an easily integrated design. Moreover, Malta has the limited land capacity and it seems a third biggest restriction to implementation of the renewable energy resources for the country. Therefore, the solar energy in Malta does not have any restriction about places depending on the potential and it can be also implemented on the rooftops. On the other hand, solar energy is founded as the most job creator potential in Malta and followed by the wind and biomass respectively. Also, impact on ecosystem, noise pollution, capacity, and effect on the quality of life were examined and solar energy became the first prioritized at all of these sub-criteria

Wind energy: Comparing with other potentials, wind energy is a good potential for Malta in energy and environmental concept. According to the priorities level wind energy comes second preferred energy potential after solar energy. Although, solar energy seemed as the best potentials for supplying energy, in environmental issues, minimum prices and for sustainable economic growth causes the wind energy to be selected more than others.

Biomass: it has the lowest priority in this study as 0.219 but it is very close to wind potential (0.257). There is an argument that biomass energy resources have some similarities with the fossil fuels and depending on the negative effect on public health, it faces with the less acceptance rate. Thus, biomass energy shows the lowest priority level in Maltese island.

7.1.2 Cyprus

Same with Malta, Cyprus has no hydropower potential. There is only tree suitable potentials were evaluated with respect to the same criteria and sub-criteria and the alternatives.

Solar Energy: For Cyprus, the results indicate that solar energy is the most suitable energy in order to invest and reach goal. The priority rate has been calculated as 0,483 and followed by the biomass with a weight of 0,353. Wind potential was stated at the last with 0,164 where it only takes wind potential mostly from north-west part.

Therefore, solar energy in Cyprus seems as the most environmentally friendly and the less noise pollutant potential. Moreover, everywhere in Cyprus has a good solar irradiation and the implementation of the solar energy technologies is not restricted by lands. In addition to this, it is the most acceptable resource by public and seems as job creator in Cyprus market. The values are represented as 0,54 for public acceptability and 0,387 for job creation. Parts and equipment are needed to be in the market and seem as one of the most important criteria to install its technology.

Biomass: Biomass potential is ranked as a second most preferred renewable energy potential in Cyprus. Agricultural biomass resources have the biggest share in Cyprus biomass sector. Moreover, it seems as the best potential depending on the land flexibility. It is the largest job creator in the renewable energy market and seems as an acceptable potential by public after the solar energy. However, it impacts the residents' life quality more other potentials.

Wind Energy: Wind potential in Cyprus is too low and ranked as the lowest after solar energy and biomass potential. Moreover, overall performance for Cyprus is good and suitable to invest but the land flexibility is very limited. Its wind potential mostly comes from the north and north east part of the country. Although, solar and biomass are ranked as a best potentials, wind energy is selected as the highest contributor for the quality of life for residents.

7.1.3 Cuba

Cuban renewable energy sector mostly belongs to the wind potentials. However because of the reducing rate of wind speed from year to year solar and biomass sector have started to be important.

Solar Energy: solar energy seems as a best alternative potential for Cuban energy sector and followed by biomass, wind and hydro respectively. Comparing with others, solar system seems as a best for environmental issues and more flexible for implementation than wind and hydropower. Depending on the social perspective, it is mostly acceptable energy potential in the region but seemed as the most costly for installation.

Biomass energy: Cuba uses mostly the sugar cane as a source of biomass while biomass energy ranked as a second important potential with a priority rate of 0.289. Biomass energy is the most important factor for social perspectives but stated at the third level for public acceptability and less job creator potential in Cuban energy sector. On the other hand, it needs more training requirement wind and biomass and selected as the most suitable for causing the accident. In other words, it was selected as the less safety potential in that region.

Wind Energy: Although wind energy plays a key role in Cuban market and the large wind farm, it was ranked as the third most suitable potential for installation. The reason can be mentioned decreasing rate of wind speed and the global warming.

Considering the environmental issue, except the noise pollution, wind energy became the second suitable potential. Additionally, it is the second most acceptable resource for implementation and selected as the most appropriate in terms of increase in life standards. However, because of causing a noise pollution, biomass energy cannot be implemented in the urban area in Cuba and has limited flexibility in terms of installation areas.

Hydropower: Hydropower potential is ranked as the lowest suitable renewable energy potential after solar energy, biomass and wind energy. Hydropower in Cuban renewable energy sector has the good share in renewable energy sector but the potential can be classified as small. Most of the installed capacity in Cuban sector is the small hydropower plants and the generation from them is low. Moreover, depending on the analyses, it seems as a less safety and the environmentally unfriendly potential for the region. Therefore, because of causing damages to natural life, it is unacceptable potential for the region. Although these negative issues, it is the most job creator potential in Cuban sector.

7.1.4 Jamaica

Jamaican energy sector belongs to importation of fossil fuels as it mentioned before. According to that, Jamaica is willing to implement renewable energies in order to protect itself from climate change and economic fluctuations. Depending on the priorities level that have been made for Jamaican renewable energy potentials, solar energy become the most crucial alternative to invest and it is followed by biomass wind and hydropower. The priority weights can be represented in following table as:

Potential	Priority Weight
Solar Energy	0.431
Biomass	0.288
Wind	0.158
Hydropower	0.122

Solar Energy: Solar energy was stated as the best potential in terms of environmental purposes. It is the best resource that is acceptable by society because of having low impact on public health and job creation. Additionally, having a less pollution of the air and causing less noise pollution are the other factors for increasing public acceptability of solar energy. However, it is less implemented technology in the region because of the installation costs. It is ranked as the most costly renewable energy technology in the region even though the subsidizing by government. Its weight is measured as 0.602 and followed by the wind energy with a weight of 0.198. Thus, it is obvious that if the low-cost power generation technologies are convenient, the energy sector is going to be benefit from it.

Biomass: Biomass energy ranked as a second suitable energy potential after solar energy with a priority rate of 0.288. With respect to social perspective, it damages the quality life negatively and ranked as third important factor for the residents life quality. Thus, the negative effects on the residents' life standards, and the similarities with fossil fuels could not reduce the importance level of biomass in Jamaica. The reason can be mentioned as there are huge suitable potentials for biomass in order to convert them into the energy. Therefore, it seems as the most flexible potential in terms of land while it has lower capacity to generate energy.

Wind and Hydropower Energy: Wind energy potential and hydropower potentials shows almost the same priority levels. Wind energy is prioritized with a weight of 0.158 while the hydropower is 0.122. However, wind energy ranked as the second environmental friendly potential while hydropower ranked as the fourth after biomass. The reason is that, whether the hydropower plants are wither small or large, they damage the nature and the habitats and cause the climate changes. They are replaced at the second and third stage of the ranking with respect to the flexibility and also belong to the cost perspective wind seems more expensive than the hydropower potential. However, depends on the environmental issue, the wind potentials should be selected as a suitable energy in order to implement rather than the hydropower.

7.1.5 Dominican Republic

Same as other countries, solar energy is the most crucial energy potentials for Dominican Republic in order to reach the goal mentioned before. Moreover, its three potentials are evaluated, which are suitable for investment, for this purpose and ranked depending on the criteria and sub-criteria. On the other hand, the priorities weights show that solar energy with a weight of 0.58 is followed by wind and hydropower. Their weights are represented as 0.257 and 0.163 respectively.

Solar Energy: According to this analyze, in order to reach the goal of the study, results indicates that with a 0,58 weight. Solar energy became the most appropriate potential to invest. This energy potential is followed by the wind (0.257) and biomass (0,163) respectively. Moreover, in Dominican Republic Island, It also shows that due to the financial constraints solar energy technology implementation is limited. From the technical perspective, parts and equipment availability, and equipment design can be seen as the most crucial sub-criteria. Thus, it indicates that, those are the major constraint to invest renewable energies which does not have available parts and equipment and an easily integrated design. Depending on this the priority rate of solar energy parts stated at the top stage with a weight of 0.634. Moreover, Dominican Republic has the limited land capacity and it seems a third biggest restriction to implementation of the renewable energy resources for the country. Therefore, the solar energy in Dominican Republic does not have any restriction about places depending on the potential and it can be also implemented on the rooftops. Its flexibility depending on the land is calculated as 0.648. On the other hand, solar energy is founded as the most job creator potential in Dominican Republic and followed by the wind and biomass respectively. Also, having less impact on ecosystem, less noise pollution, high capacity, and positive effect on the quality of life were examined and solar energy became the first prioritized at all of these sub-criteria.

Wind Energy: Wind energy potential ranked as a second most important and the suitable energy potential to invest as an alternative energy. Being a safety plant, job creator, having a positive effect on the residents' life and less costly then solar energy technologies stated the wind energy at a second level of the priority ranking with a weight of 0.257. Therefore, having a noise pollution reduces its weight accordingly. Although solar energy performance on the natural issues, wind energy provides sustainable electricity with low prices and contributes economic growth more than solar energy. So they cause to be preferred as a second potential after solar energy.

Hydropower: Despite having a largest share of hydropower potential in Caribbean region, hydropower potential selected as a last prioritized renewable energy among other potentials. The reasons can be briefly listed as:

- There is an argument for sustainability of the hydropower resources
- Impacts on the nature and habitats
- Cause climate changes
- Less flexibility in terms of land

Moreover, it is ranked as unfriendly renewable energy potential for the ecosystem and causes some noise pollution for the region. Additionally, it is selected as less safety power plant in the region and has less parts availability. Moreover, according to the weights of plant safety, impacts on quality of life and having the risk in sustainability cause to reduce the acceptability of the public.

7.1.6 Singapore

Solar and Biomass energy: Singapore has almost no renewable energy potentials except biomass and the solar energy. Despite this issue, in order to have sustainable economic growth and to satisfy increasing rate of electricity demand Singapore has an increasing rate of investment on renewable energy sector. Solar energy plays a key role for the country and becoming to have an important amount of share in energy sector. Being environmentally friendly, being flexible in terms of land, being safety and having a positive effects on the quality of life carries the solar energy at a most prioritized potential. Therefore it is followed by the biomass which has almost same characteristic with the solar energy. Its low effect on quality of land, being fewer jobs creative and less safety pushes its importance lower than the solar energy potential.

Chapter 8

CONCLUSION AND RECOMMENDATION

Energy is one of the most important key factors for residents, industries, agriculture and transportation etc. With an increasing rate of energy demand, the governmental and non-governmental organizations try to find a way to satisfy it. Moreover, energy production and sustainability is the major determinant for economic growth. Therefore, most of the countries, especially small island countries, are mostly dependent on the fossil fuels in order to generate energy. Thus, they belong to the importation of that from other countries. Small island countries are dependent to the fossil fuels more than 90% which is the most important contradiction for development. Moreover, this dependence creates economic, environmental and political problems. Because of this reason, small island countries try to use their own potentials for sustainable energy supply and in order to survive.

In this study, the major and suitable renewable energy potentials are evaluated, (i.e. solar energy, biomass, hydropower and wind) according to the generation capacity. These potentials are examined in order to select the most appropriate one in order to increase contribution to the energy sector. The potentials are evaluating by using AHP method with five main and thirteen sub-criteria in order to reach the goal. The model is prepared by stated levels as goal, criteria, sub-criteria and the alternatives and in order to have unsuspicious result the inconsistency ratio is considered. As a result of this work, the following conclusions are founded:

- Economical aspects are founded as a most crucial criterion with the priority level of 0.438 and followed by the technical, location; social and environmental aspects respectively. Thus, while doing the selection process of most appropriate renewable energy to contribution of the energies for selected small islands, environmental issue has to be considered first. The main reason for this aspect is to evaluate the environmental impact and the pollution rates of the technology. Therefore, renewable energy generates benefit at a point of economic issue. it creates job opportunities which plays a key role for economic development and healthy economics. Additionally, the benefit is reached while the workers who work in renewable energy sector spend their income in local economy. This activity creates huge economic activity and cause the development in economy. In other point of view, renewable energy can be cost effective which means that investors in new technologies can save money from decreased fuel used energy bills than the invested capital

- Technology became the second most crucial indicator for selecting renewable energy resource for small islands with the priority level of 0.251. it can be described at a point of assessment of proximate technologies' cost of generations and financial savings for technologies. It also evaluated depending on equipment design and complexity, plant design, parts and equipment availability, plant safety, maintaining and training requirements. So, with respect to these sub-criteria technological issue should be evaluated at a second stage.

- Depending on the location criteria, best alternative renewable energy for the small island country is evaluated with respect to flexibility of plant area and its size and location became third most important criteria for implementing renewable energy technology. Therefore the priority level of this criteria is founded as 0.149 and became the third most important criteria.

- Social issue is ranked as a third most important criteria out of four criteria. Moreover, implication of the renewable energy technologies and selecting best renewable energy potential can be differ in this aspect in terms of: i) disparity in income, ii) disparity in standards of living, iii) disparity in educational level and demography iv) difference among urbanized and rural society. Therefore, depending on social aspects, society can benefit by implementing the renewable energy technology such as improved health, consumer choice. Work opportunities, technological advances, greater self- reliance etc.

- The pollution of the environment is one of the most crucial indicators for renewable energy technology implementation. And the pollution takes the important place and mostly linked to increasing rate of using energy with using fossil fuels. Besides this, pollution and the changing the regulation of the environment cause the climate changes and cause many problems which are mentioned before. Depending on this, environmental aspect becomes the third important factor with 0.081 priority level to decide whether to invest on renewable energy technologies or not.

Therefore, for making the renewable energy sources and implementation of their technologies more attractive, authorities should put the law like subsidies. For instance Turkish government put the law regarding to the attracting the renewable energy technology implementations which is named as Law on Utilization of

Renewable Energy Sources for the Purpose of Generating Electrical Energy No: 5346. As explained in law, solar mentioned as the most important and the purchasing price is set as highest when it is given in the system together with biomass based generation. The domestic equipment and the technologies for the renewable energy issue should be supported by the government which also contributes the economy at the same time. This increase in implementation of the renewable energy technologies will also cause the low price electricity generation and maintaining the stability and efficiency in providing electricity.

The result of the study may be a guideline for the authorities in shaping the energy policies and also may be good roadmaps for the environmentalists, non-governmental organizations and local public. Moreover all the results may be evaluated together for making the policies for economic and energy issues.

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