Assessing Feasibility of Renewable Biomass Resources and their Contribution to Economic Growth

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Dedicated

To

My Parents

Acknowledgement

In the name of Allah most gracious and most compassionate, all praises and thanks to Allah to give me all the blessing and the strength Peace and blessings of ALLAH on His Prophet Muhammad ﷺ the most perfect source of ALLAH's guidance and blessings

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Abstract

Pakistan is facing shortage of energy from last several years as there is considerable gap between energy generation and its demand Generation of energy mainly depends upon non-renewable energy sources which are causing the problem of heavy import bills and circular debt and recently the circular debt of Pakistan has reached to Rs 337 7 billion The country is blessed with abundant renewable energy sources but all of these are not exploitable because of technical and financial barriers The renewable biomass is most promising source of energy as they are readily available and easily exploitable This research provides the overview of renewable biomass sources (Short rotation energy crops, non-woody grasses, oil crops, agricultural residues, wastes and livestock manure) and their impact on economic growth It was observed that all these resources was exploitable without compromising other food crops and agricultural areas in an environmentally positive way and has positive impact on economic growth as the variable of electricity through renewable energy sources is significant and positive related to economic growth at 5% significance level The farmers can be trained for the generation of these resources which will improve their living standards The technologies to convert these resources into different forms of energy are also available within the country at very cheaper costs Therefore, by introducing biomass, everyone among the public can contribute to the resolution of energy deficit that will lead to high economic growth

Chapter 1

Introduction

Energy crisis in Pakistan is a serious issue It is often recorded that there is shortage of electricity of 8-10 hours and 16-18 hours in urban and rural areas respectively (Javaid et al (2011)) Pakistan is third largest country of the world in natural gas consumption, but presently it is also facing the worst gas shortage calamity (Ahmed et al (2013)) Domestic energy demand in terms of electricity was 18,000 megawatt and domestic production was 13,240 megawatt, resulting 4,760 megawatt shortfall or gap during 2013-2014[1] According to Oil and Gas Regulatory Authority, the supply and demand gap of gas has reached to 2 billion cubic feet per day at the end of 2014 If this shortage is not addressed properly, it might become national security threat (Harijan and Uqaili (2013))

For sustainable economic growth of any country, availability and production of enough and cheaper energy is essential, therefore, there is a great need to fill the required energy gap in Pakistan Energy can be generated through number of ways and methods and each way has specific requirements in terms of technology, financial budget and time span For energy generation there may be three foremost possibilities First, fossil fuels (oil, natural gas, and coal etc) Second, renewable energy sources including solar, wind, nuclear and hydro Third renewable biomass like wood, energy crops agricultural residues, livestock manure, food waste, industrial waste and its co-products

[1] http //app com pk

Fossil fuel resources is the important and basic source of energy and 80% requirements of world energy demand is being fulfilled by these resources (Bhutto et al (2011)) On the one hand, these resources have the potential to generate huge amount of energy at a single place, but on the other hand, fossil fuels are also the biggest source of greenhouse gas emission These gases are harmful for climate and cause of global warming They are also responsible for the extensive destruction of environment, ozone layer and human health It is also a fact that fossil fuels reservoirs are developed by natural practice They are limited in quantity and erratically distributed on earth In terms of stock, storage and additional reserves, even, the rich countries are not in a certain or secured position (Husain (2010))

In addition to that, import of fossil fuel carries heavy cost for the country State bank of Pakistan paid a total of $6 69 billion for the import of petroleum products and crude oil during the July-Nov 2014[2] Fluctuation in price of oil in international market and diverse global trends also badly affect energy cost (Asif (2009)) The heavy import of oil has created the problem of circular debt in energy sector Pakistan's energy sector circular debt was Rs 180 billion at the end of Feb 2014[3] Pakistan is one of the big natural gas dependent country in the world It has many reserves of gas but these reserves fall short of the total demand The heavy capital required for drilling is also a barrier to harness this source of energy

According to the Federal Minister of Water and Power, Pakistan is blessed with the plenty amount of coal reserves It is estimated that only in Thar 175 billion tons coal is available

[2] http //www dawn com

[3] http //www dawn com

However, energy production from coal is not an easy task It requires heavy technologies and sufficient expertise in judging the quality of coal Dr Samar Mubarik Mand had initiated the Thar coal project by claiming that he could produce electricity without the help of multinational companies Unfortunately due to the lack of consensus among Government authorities and insufficient funds, the fruits of this project could not be obtained so far

In this situation, option of advancement in alternate energy generation technology is getting popular and going to become an emergent choice of experts Compare of fossil fuels, they are environment friendly and more secure source of energy generation The geology and geography of Pakistan is much suitable for various types of renewable energy generation sources Coastal areas of Pakistan are feasible for windmills and desert areas are best for solar energy while productive areas where agriculture and livestock are abundant, installation of bio gas plants is a suitable option Pakistan also has the world's best canal system where we can use micro hydro plants (Khan and Qayyum (2009)) and (Sheikh (2010)) Although Pakistan is blessed with plenty of renewable sources but only those resources are exploitable which stand on the bases of proven techno economic feasibilities (Sahir and Qureshi (2008)) The energy production from wind does not pollute the environment and decreases the import of fossil fuels However, the initial cost of installation of solar panel and wind mills is very high, maintenance and repair of this kind of machinery is also not an easy task that's why only government or large scale organizations can initiate these type of projects (Mahmood et al (2014))

Another option of renewable energy is the renewable biomass Biomass is a biological material which can be derived from living organisms Energy generation through biomass is also an emerging sector There are seven major material categories from which biomass energy can be generated i-e Virgin wood, energy crops, agricultural residues, livestock manure, food waste, industrial waste and its co-products Livestock manure can be converted into fuel after specific process which is less expensive way to generate the energy There are certain types of plants which produce huge amount of biomass in a short duration of time The production of these plants has dual advantage, in that, the technology and inputs required are very small and the environmental impacts are not negative Systematic use of biomass can save the time of women and children that they spend in collecting woods for cooking and heating Renovation process can change the bulky biomass into fuel which is economical to store and easy to transform (Demirbas (2004)) Biomass for energy can be used directly for heating It can be used indirectly by converting into liquid and gaseous fuel too (Demirbaş (2001)) Among all other renewable energy sources, biomass is unique because it can produced with low-cost, started with very small budget and easily available and there availability is de-centralized (Amjid et al (2011)) The raw material of biomass energy is mostly invaluable and easily available that has no use immediately This raw material can produce energy with simple technology in environmentally acceptable manner (Kuçuk and Demirbaş (1997))

1.1 Research Purpose

The purpose of this research is to survey the various kinds of biomass resources, to analyze their feasibility and to do a cost benefit analysis of these resources The study also analyzes the impact of renewable energy on economic growth

1.2 Objectives

The following are the objectives of the research

1 Assessing the feasibility of renewable biomass as renewable energy resources
2 Making comparison of various sources of renewable biomass
3 Estimating or analyzing the of impact of renewable energy resources on economic growth

1.3 Significance

The importance of energy crisis in Pakistan cannot be overstated, however, the available energy solutions could be taken only by the governments and large scale organizations This study provides a guide on alternate energy solution where ordinary farmers could contribute to the solution of energy crisis

Chapter 2

Literature review

The research in the last decade shows great significance of the potential of renewable energy sources as fossil fuels are not enough to meet the growing energy demand of the world Almost all countries have been emphasizing the generation of energy from renewable sources because energy generation with these resources helps in mitigating environmental degradation The great emphasize of renewable energies may be attributed to the socio-economic sustainability of developed countries and industrialization of developing countries (Mohammed et al (2014))

The literature review is divided into following two sections

i Renewable energy sources including renewable biomass

ii Effects of renewable energy source on economic growth

2.1 Renewable Energy Sources Including Renewable Biomass

Renewable energy sources are replenished by the nature on regular basis e g the sun, the wind, water, earth's heat and plants Renewable energy technologies turn these resources into exploitable form of energies generally in electricity but sometimes in heat and mechanical power Three centuries ago, world fully relied on the renewable sources of energy that was fully sustainable and once again economies have been converting to the past The revival of renewable energy sources is because of the depletion of fossil fuels and their impact on environment There are different forms of renewable energy like, solar, wind, hydro, biomass, geothermal, tidal and wave energy Currently renewable energy is contributing 15% to 20% of world's energy consumption (Herzog et al (2001)) There are many types of renewable energy sources like,

- **Solar Energy**
- **Wind Power**
- **Hydro Electricity**
- **Biomass Energy**

Sun is primary source of energy on earth and this energy is storable The energy from sun is clean and environmentally positive with zero emissions Most of the developing countries are on sunny belt area and have the potential to generate electricity from sun India and Pakistan both have the 250-300 sunny days annually and 8-10 sunny hours daily which can be utilize to generate enough amount of energy [Kumar and Karthick (2011), Khalil and Zaidi (2014)] calculated the potential of solar energy in different cities of Pakistan and concluded that 0 22 KW was the highest potential and 0 17 was the lowest available potential in these cities in a day Pakistan also has launched the Quaid-e-Azam solar park a 1,000 thousand megawatt photovoltaic power station in Bahawalpur It has to complete at the end of 2016 and it would be the biggest solar power plant in Pakistan and one of the biggest power plant in the world Globally there are two types of technologies through which solar energy is being captured e g active and passive Solar panels are the example of active technology and energy- efficient windows and green houses are the examples of passive technology Buildings are also built to serve the purpose of this type of technology, where heavy thermal mass is used to attract more heat and insolation is used to store this heat (Foroudastan and Dees (2006)) Apart from these two main types of technologies, there are many small scale technologies to harness solar energy like , solar heater, solar cooker, solar water heating etc Recently, the price of solar electricity has been calculated 30 cents per kilo watt hour for grid connected areas and for remote areas the prices are less and developing countries have many remote areas which can be electrify through solar energy (Foroudastan and Dees (2006))

China is one of the rapidly growing economies that requires substantial amount of energy Chinese government has been paying much attention toward the non-fossil energy sources, as she set the target of getting 10% renewable energy of its total consumption by 2020 The wind industry of china has the potential to be ranked first in the world The energy generation from wind was 50 million MW in 2010 and the target is eight time higher than this amount till 2020 (Zhao et al (2014)) The geological and geographical situation of India is appropriate for various renewable energy sources and she is utilizing these resources efficiently At the end of March 2013, the installed capacity of renewable energy source was 28 1 GW Wind accounts for 68% of this capacity making India's wind industry fifth largest in the world Although the share of renewable energy is increasing, but still India has many unexploited resources [The renewable energy India expo (2013)] Like other developing countries, Bangladesh is also energy deficit country Only 10% rural population has access to national grid station and may be some remote areas will not be connected to grid stations until next 30 years For such kind of situations alternate energy resources are the best option Bangladesh is awarded with different resources of renewable energy It can obtain biodiesel from Algae and Jetropha, both are in plenty amount and can provide the enough amount of biodiesel The average solar irradiation is 4 to 6 5 kWhm $^{-2}$day^{-1} and the maximum sunny months are March-April Bangladesh has 724 km long coastal line that can be used for wind mills Low heads of water in river can be the best option of hydroelectricity (Habib and Chungpaibulpatana (2014)) According to different surveys of wind speed conducted by the Metrological Department of Pakistan, it is estimated that Pakistan has the potential of wind energy in the coastal areas of Sindh and Baluchistan It is concluded that the wind speed is suitable to generate energy of almost 43,000 MW on the coastal line of 9700km^2, but due to the constraints of land utilization area only 2481km^2 area is available to install wind mills that can generate the 11,000 MW electricity (Farooq and Kumar (2013))

There are machines, called wind turbines which convert kinetic energy into electric energy Horizontal Axis and Vertical Axis wind turbines are two types of turbines which are used to generate electricity Horizontal Wind Turbines are the most common and popular turbines The main parts of a turbine are rotor, gearbox tower and generator Rotors are the blades which rotate and turn the gears and generator turn the kinetic energy of blades into electric energy PISE et al ()

The water at work or in motion can produce electricity that is renewable and environment friendly The riverine countries are blessed by the nature and have the advantage to produce electricity The Yarlung Tsangpo situated in Tibet is high altitude river which flows along the Himalaya If it is used to generate hydroelectricity it would be the world's largest project as it has the potential to give power to 60 gigawatt power station, but the area possesses its own eco system and this massive project could be dangerous for ecology of India and China[4] Bhutan is also one of those countries which has many number of rivers and has the potential of 30,000 megawatt capacity It has exploited only 1480 megawatt which is just 6% of this potential India is providing technical assistance and finance to harness this potential and 75% of electricity generated in Bhutan is exported to India which generates 40% of Bhutan's revenues[5] Pakistan also owns abundant resources of hydroelectricity which are mostly in the north side of the country The installed volume of hydroelectricity is 6595 megawatt and the major share of this capacity is in North-West Frontier Province (NWFP) [Private Power & Infrastructure Board]

In hydroelectricity, hydro power plant convert the kinetic energy of water into mechanical energy and then it is converted into electric power Hydro power plant can be ranked according to their size i e micro, mini, small and large Micro hydro power plant can generate electricity up to 100 KW, and mini power plant can serve until the need of 1 MW electricity Whereas small and large can generate 1MW to 30MW and more than 30 MW respectively (Castaldi et al (2003))

The situation of Pakistan regarding energy is not different from other developing countries Renewable energy sources are enough to overcome the energy crisis of the country Energy

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[4] https //www chinadialogue net/article/show/single/en/6781-World-s-largest-hydropower-project-planned-for-Tibetan-Plateau
[5] http //www internationalrivers org/blogs/328-5

from renewable energy sources has been the part of government policies since 1980s but until now the progress is very slow (Mirza et al (2008))

In past biomass was used mostly in household activities for cooking and heating Research has proved that biomass can be used in industries as a fuel as well By et al (2009) assessed different sources of biomass to use in cement kilns as a fuel in Ethiopia The case study showed that there was great opportunity for government to reduce the oil import and use local resources like coffee husk, cotton residues, jetropha, castor bamboo etc

Biomass energy is one of the renewable sources of energy that is very frequent in developing countries In 19^{th} century biomass was main source of energy as firewood, later on it was replaced by fossil fuels It has number of features because of which it has been gaining popularity in the world, mainly in third world countries (McKendry (2002)) Biomass is the only form of renewable energy source that can be in the shape of solid, liquid and gaseous fuel It is storable and transformable (Hall and Scrase (1998)) It is also being practice in developed countries It can be turned into different forms of energy or fuel with different technologies Feng et al (2009) conducted a case study of Tibet The main source of residential energy is biomass because it is easily available This biomass is being used with inefficient methods Its efficiency can be improved with Residential Biogas Model (RBM) It is environment friendly and economically viable

There are different forms of biomass, woody biomass, biodiesel and biogas The most common technologies for biomass energy are direct combustion, co-firing, gasification, pyrolysis, anaerobic digestion, and fermentation On earth 30% area is covered by forests from which 25% is natural forest and 5% is cultivated The average area of forest varies geographically Biomass is contributing around 14% of world's total energy consumption but 90% of wood fuel is being used in the developing countries of the world Forest product industry generates two kinds of residues, logging residues and industrial by-products These two residues can be the striking source of fuel if properly handled (Parikka (2004)) There is significant potential of short rotated energy crops These crops can be produced without compromising the area reserved for food Hoogwijk et al (2005) evaluated the availability of three types of abandoned land which are agricultural land, low-productivity land and rest land at global level for 2050 and 2100 Pasture area is also excluded from the analysis It is predicted that the abandoned land has the highest share of 10% of surface of earth in energy crops potential There are some species of large woody grasses that can serve as biomass energy Bamboo is one of these woody grasses with more than 1200 species Its height varies from 10 cm to 20 m China, India, Bangladesh and Thailand are Asian countries that contain more than 1000 bamboo species Agricultural Research Service of United States has examined the nine bamboo species for fuel properties These plants were grown under controlled conditions The elemental ash properties were estimated The heating value of these species was observed 19 09–19 57 GJ/t for dry bamboo (Scurlock et al (2000)) Sritong et al (2012) examined the two species of bamboo, Gimsung bamboo and Tong bamboo as a renewable energy source in Thailand They compared the bamboo qualities with other sources of biomass like, bagasse, palm fiber, empty fruit bunch, rice husk etc and found that it was appropriate for electricity production High Heating Value (HHV) of both bamboos was highest to the all other compared sources

The lowest ash of palm leaf, Gimsung bamboo and Tong bamboo were 0 72%, 3 70% and 2 70% respectively Sritong et al (2012) examined 22 species of Halophytes that are in abundant in the coastal region of Pakistan It is non-food grasses that can be used for bio ethanol This kind of grasses can be cultivated on non-cultivatable land with saline resources

Biogas is another form of biomass energy in which biomass inputs are converted into gas energy Many villages in Pakistan do not have excess to gas and electricity, but almost every village has livestock and agro waste There are 159 million animals that produce almost 652 million kg of manure daily The villagers' are using these livestock and crops residues in traditional way This traditional practice is not economical and environment friendly This animal waste can generate 16 3 million m^3 biogas per day and 21 million tons of bio fertilizer per year by biogas plant (Amjid et al (2011)) Pakistan is getting 23 5% of its energy consumption from the traditional biomass, which has the efficiency of 10% Renewable energy technologies are growing rapidly in Pakistan Pakistan Council of Renewable Energy Technologies (PCRET) is playing significant role in introducing the renewable energy technologies in rural areas of Pakistan It has established over 1200 biogas plants all over the country

Biogas is the most compatible source of energy to compete the growing energy demand Biogas plant manages the waste to produce gas that is environmentally positive The biogas technology is very simple and raw material is readily accessible The unproblematic affordability of biomass elevates the socioeconomic life of farmers (Ali et al (2013)) The form of energy which is locally available, reasonably priced and easily managed by the natives, is always a model source of energy Anaerobic digestion of energy production system is one of the technologies that convert animal and crops residues into energy This system is very simple, cost effective and can function in urban and rural areas on both small and large scale (Amigun (2012))

Jatropha Curcas is gaining fame as a feasible source of biodiesel because of its strange features It produces non edible fruits, survives with poor quality of soil, needs less water and easily stays alive in sever heat Raja at al (2011) analyzed the jetropha oil as a bio diesel in India The physical properties of jetropha oil are similar with biodiesel These seeds can be pressed with any simple oil presser 4 kg jetropha seeds provide 1 liter jetropha oil that can be used in any diesel engine without modifications The viability of jetropha oil has also been proved as a jet fuel in New Zealand Biodiesel from jetropha is also practiced in Pakistan by Pakistan State Oil (PSO) with the assistance of Alternate Energy development Board (AEDB) and Pakistan Council of Renewable Energy Technologies (PCRET) Due to its agricultural base and climatic conditions, the cultivation of jetropha in Pakistan was proved feasible The first fruit was obtained after seven months of cultivation The oil was tested in van engine with the blend of 10% biodiesel There is enough potential of getting energy through renewable energy sources mainly through biomass The energy from these resources is easily and economically exploitable but due to the lack of interest by the Government authorities, it is not being properly exploited If the available resources of renewable energy sources properly utilized, they have ability to manage and mitigate the energy crisis of Pakistan (Chaudhry et al (2009))

2.2 Determinants of Economic Growth

There is huge research on determinants of economic growth and different researchers emphasize on different factors which effect economic growth Such as Shehbaz et all (2008) consider financial development, foreign direct investment, remittances, trade openness and inflation They used quarterly data from 1991 to 2007 They used ARDL approach to check the relationship between economic growth and selected variable Their study shows positive relationship between economic growth and financial development, remittances and trade openness where as inflation negatively affect the economic growth Another empirical study has been carried out by Rehman and Salahudin (2010) more or less with similar variables They used market capitalization, financial development, financial instability, inflation rate, foreign direct investment, literacy rate and stock market liquidity They used annual data for all variables from 1971 to 2007 They also used ARDL bonds to check the relationship between economic growth and selected variables The main focus of their study was on financial development and their study shows positive and significant relationship between economic growth and financial development Apart from financial development and other macro variables, some researchers emphasize on energy variables because deficiency of energy has negatively and badly effect the economic growth of Pakistan To check the impact of electricity consumption on economic growth Shehbaz and Fridun (2011) used the ARDL bond approach and their result shows that economic growth leads to electricity consumption but not vice versa

Energy from renewable sources is a preferable option especially for those countries which have less amount of fossil fuel Energy generation options from renewable sources can be explored, if the technical and economic potential exist along with theoretical potential Many renewable energy sources have similar economic features, e g , they have high fixed cost but low or zero variable cost (Heal (2010))

Efficient use of locally available renewable energy sources can mitigate the foreign energy dependency, boost up economic development and create equilibrium between environment and sustainability The continual supply of energy at affordable price decreases the imports of fossil fuels This leads towards the improvement in Balance of Trade and currency stability (Ozturk and Bilgili (2015)) Exploitation of renewable energy sources generates the employment in developing countries Installation of solar panel and wind mills require heavy amount of labor at initial level, but for running requirement less employees needed The energy from biomass requires simple technology but it needs involvement of workers for running and management on daily basis Singh and Fehrs (2001) has checked the potential of job creation through the renewable energy sources in US They estimated the number of workers required from fuel gathering to the running position of renewable energy power plants The result showed approximately, 36, 4 and 13 workers for solar PV, wind power and for co-firing biomass were needed every year respectively, in order to produce 1 MW of energy from each resource Llera et al (2013) has discussed the case study of Spanish PV industry for forecasting the job creation through the renewable energy technologies They divided the supply chain of PV technologies in eight different stages and analyzed the job creation in all stages They found that to generate the 1 MW of energy through PV almost 29 5 workers would be employed or 51,500 hours of labor required

Moreover, the renewable energy technologies penetrate the way for new opportunities of development

Energy from locally available renewable sources creates new employment opportunities for domestic labor and sufficient energy for every sector of the country This ultimately results high economic growth Apergis and Danuletiu (2014) investigate the long run relationship between renewable energy and economic growth They studied the 80 developed and emerging countries of different regions of European Union, Western Europe, Asia, Latin America and Africa They also investigate the sign of direction of causation between two variables They end up with the result that renewable energy and economic growth have long term positive relation in selected countries The correlation between the renewable energy sources, economic growth and mitigation of greenhouse gases is examined by Sebri and Ben Salha (2013) They use trade openness and omission of carbon dioxide (CO2) as a control variable The results of their study show the positive impact of renewable energy consumptions on economic growth Trade openness and CO2 also play positive role to boost up the renewable energy industry Trade openness helps to promote the Green Technology transfer to exploit the resources, on the other hand omission of CO2 put pressure on policy makers to reduce its omission and develop renewable energy industry Similar Study has been conducted by the Silva et al (2011) They checked the impact of electricity generated by renewable energy sources on economic growth They took four countries USA, Denmark, Portugal and Spain and used Structural Vector Autoregressive (SVAR) methodology to check the impact of electricity generated by renewable energy sources on economic growth Their results show that at the starting electricity generated through renewable energy has negative impact on GDP growth except USA but later it has positive impact on GDP growth and also helps to reduce carbon dioxide emission Ragwitz et al (2009) analyzed the economic effects of all available renewable energy sources in all member states of European Union with the help of NEMESIS and ASTRA models They claimed that energy generation from renewable sources grew by 30% from 1997 to 2006 The share of electricity from renewable sources in consumption was 13 7% in 2006

Silva et al (2012) has estimated the impact of renewable electricity on economic growth and carbon dioxide omission for four different countries Denmark, USA, Spain and Portugal The purpose of selecting these countries is their different geological and economical situations They used three variable SVAR approach and data was used from 1961-2004 They have found that initially electricity from renewable energy sources harm the economic growth except for USA, but it significantly reduce the omission of carbon dioxide Later, with the development of the technology of renewable energy sources electricity becomes cheaper and it affects the economic growth positively Similar study has been conducted by Bozkurt and Destek (2015) on OECD countries Four countries are selected, two are developed countries US and Germany, where as two less developed countries Italy and Turkey has been selected They used auto distributed lag approach to investigate the relationship among economic growth, total number of labor, renewable energy consumption and gross fixed capital Their study concluded that renewable energy consumption was positively related with economy of US and Germany but negatively related with the economy of Italy and Turkey We can generalize from their results that renewable energy positively affect the economy of developed countries and negatively to the less developed countries

The modern world is not interested just in economic growth but also in sustainable growth Energy is backbone of the country's growth but conventional sources of energy are not only limited but also affect the environment badly Due to which economies are focusing on renewable sources of energy, even some developed countries like Denmark are emphasizing to produce 100% of their energy from renewable sources Producing of energy through reproducible biomass has got much attention in developing countries because of its easily availability and simple technology (Hoogwijk et al (2005)) Pakistan is blessed with the potential of renewable energy sources but still this industry is not developed and not much empirical and quantitive research is available on it

Chapter 3

Methodology

The objective of this study is to explore the potential of renewable biomass in Pakistan and to make comparison of different sources of renewable biomass The study also analyzes the impact of renewable energy on economic growth of Pakistan To accomplish the objectives, the methodology chapter composes of following sections

1 Assessing the feasibility of renewable biomass
2 Making comparison of various renewable sources of biomass
3 Investigating the relationship between economic growth and renewable energy sources

Section 1

3.1 Feasibility of Renewable Biomass

The feasibility of renewable biomass is explored in different areas of Pakistan The comparison of different sources of renewable biomass is made on the basis of five points mention below

1 Cost of initiating project
2 Skills required
3 Expected revenue
4 Environmental Impacts

The information available from secondary sources is collected Expert's opinion about different sources of biomass i e biodiesel, woody biomass, biogas and other sources is gathered through Key Informant Interviews

Section 2

In this section we want to analyze the impact of energy from renewable resources on economic growth In fact, this study intended to analyze impact of renewable biomass on the growth but unfortunately, the data on the renewable biomass is not available However, the renewable biomass is a part of the renewable energy resources and an increase in renewable biomass would add in the renewable energy Therefore the impact of this increase could be analyzed by using the data on the renewable resources

Under this section models are discussed to find out the effect of renewable energy sources on economic growth While calculating effect of renewable energy sources on economic growth, the study takes care to find unbiased estimate of renewable energy sources on economic growth There are two main sources of bias in a time series Data

1 Missing variable bias
2 Spurious regression

To deal with missing variable bias, the study adopts encompassing methodology A general model for economic growth is constructed based on existing models and it is reduced after testing restrictions It is well known that if a model is over specified, it contains relevant variables as well as some irrelevant variables, the parameter estimates are unbiased and the model can be simplified by testing appropriate restrictions on variables Therefore it's better to start with general model

3.2 Model Selection by Encompassing

A number of variables and models have been used by pervious researchers Ignoring any of these variables will cause omitted variable bias, while including all variables may make the model difficult to handle and insignificant results Therefore this study uses the encompassing approach to find the best model for economic growth

The encompassing approach is discussed below

Suppose M1, M2 Mn are models that have been used by the researchers

M1, M2 Mn will be estimated and separately ranked according to their standard error

The model with lowest standard error is selected and compared with other selected models and following hypothesis is construct,

H_0 (1) M_i encompasses M1

H_0 (2) M_i encompasses M2

H_0 (n) M_i encompasses Mn

The model for which H_0 is not rejected, would be ignored The variables of the models, which would not be encompassed by M_i would construct our specific model Then with the help of general to specific methodology, the independent variables which would have insignificant effect on dependent variable would be excluded after applying some restrictions

3.3 Avoiding Spurious Regression

To avoid the spurious regression the series will be checked for stationarity The spurious regression occurs if variables in a regression model are non-stationary and are not cointegrated Therefore, this study will test variables for stationarity and Cointegration by following tests

1. Unit root test
2. Engel and Granjer test

In order to investigate the possibility of cointegration, it is first necessary to determine the existence of unit roots in the data series For this, we apply the Augmented Dickey Fuller test

$$\Delta y_t = \beta y_{t-1} + \sum_{i=1}^{P} \delta \Delta y_{t-1} + \varepsilon_t$$

Here Δy_t is first difference series If $\beta = 0$, it means the series is non-stationary or it has unit root and $\beta < 0$, it means the series is stationary

3.4 Co-integration

Test that all variables are unit root or stationary

1. Verify the stationarity of all variables

2. Run the regressions and obtain residual series

$$Y_{it} = \alpha_i + \beta_i X_{it} + \varepsilon_{it} \qquad (3.2)$$

Where, X_{it} is a vector of all independent variables

Apply unit root test to the residual series ε_{it} obtained in step-2, if the residuals are stationary, cointegration exists The same method has been adopted for testing co-integration This is called Engel Granger procedure for testing co-integration

3.5 Error Correction Model (ECM)

If co-integration exists, it shows long run relationship between dependent and independent variables Then ECM has applied to check the short run relationship among the variables

The basic form of ECM is given below

$$\Delta Y_t = \alpha + \beta_0 \Delta X_{t-i} - \beta_1 EC_{t-i} + \varepsilon_{it} \qquad (3.3)$$

Whereas the single equation ECM is

$$\Delta Y_t = \alpha + \beta_0 \Delta X_t - \beta_1 (Y_{t-1} - \beta_2 X_{t-i}) + \varepsilon_{it} \qquad (3.4)$$

The effect of increase in independent variable on dependent variable is depicted by β_0 in short run and the speed of returning to the equilibrium after abnormality is shown by the β_1 If the ECM methodology is suitable then the result will be $-1 < \beta 1 < 0$ The variations among dependent and independent variables will tend to stable long run relationship, if the value of ECM is negative and significant

3.6 Data description

The focus of this study is the economy of Pakistan For the potential of renewable biomass secondary available data is used To check the impact of renewable energy on economic growth the data from World development Indicator from 1980-2013 has been used

3.7 Explanation of Variables

The following variables are used in this research

Variables	Definition
Growth rate of GDP (Gr_Y)	Growth rate of GDP is calculated by subtracting the previous year GDP from current year' GDP and then divided by the previous year GDP
Capital (K)	Log of gross capital formation (constant LCU)
Labor (L)	Log of employed labor force
Combustible Renewables and Waste (Cre)	Combustible Renewables and Waste (% of total energy)
Electricity Production from renewable sources (Er)	Log of Electricity Production from renewable sources (KWh)
Electricity Production (En)	Log of Electricity Production (KWh)
Financial Development (FD)	Financial development proxies by the credit to private sector as share of GDP
Foreign Direct Investment (FDI)	Financial openness proxies by foreign direct investment share of GDP

Remittances	Foreign remittances received % of GDP
Trade Openness (TR)	Trade openness is calculated as [(exports + imports)/GDP] The values are in constant local currency unit
Annual Inflation (INF)	Annual inflation is calculated by subtracting the previous year consumer price index (CPI) from current year' CPI and then divided by the previous year CPI
Market Capitalization (MC)	Market capitalization is measured by the gross capital formation % of GDP
Literacy Rate (LLTR)	Log of literacy rate measured by the number of enrolled in primary education
Stock market Liquidity (LSTL)	Log of stock market liquidity measured by the stock traded as share of GDP
Electric Power Consumption (LEC)	Log of electric power consumption in KWh per capita

Chapter 4

Feasibility of Biomass Resource

This chapter discusses the requirement, potential and technical analysis of biomass sources Biomass is a biological material, derived from living organisms which is renewable and sustainable It can be converted into many forms of energy like electricity, heat, biodiesel and ethanol There are many source of biomass that are mentioned below

- Short Rotation Energy Crops
- Agricultural Energy Crops
- Oil Crops
- Non-Woody Grasses
- Aquatics
- Agricultural Residues
- Livestock manure
- Municipal Solid Waste

4.1 Short Rotation Energy Crops

Many biomass sources comprise of different woods that are available during whole year and the consumers do not have to rely on single source Some researchers predict that in coming years biomass energy will contribute 10-45% of world primary energy demand and many of them conclude that short rotation energy crops would be the particular best imperative biomass source (Berndes et al (2003)) There is no special technology and inputs require to grow these crops but to convert them into energy some existing technology which is being practice for fossil fuels can be used This type of technology is being discussed at the end of this topic These woods varies in nature and characteristics Some of these are mentioned below,

- Willow
- Bamboo
- Popular

4.1.1 Willow

There are approximately 526 species of willow (salix) Many of them are in Northern Hemisphere and very little in Southern Hemisphere There are 375 species of willow in Asia which are 71 29 percent of total worlds 'species Among these 375 species, 328 are local or native to Asia (Fang (1987)) Centuries ago, willow was used for soil conservation, wind breakers, baskets and medical by the Egyptians and Romans (Keoleian and Volk (2005)) Later on its usage was decreased for these purposes because other material is available At that moment, its other features are observed and it is cultivated to use as a source of biomass

They are fast growing and in the fourth season of their plantation, they are ready to harvest and their height is almost 15-20 feet The harvesting can be done any time after fourth season after fallen the leaves

Plantation requirements of some of willow species are presented in the table 4 1 as a source of biomass

[redacted]

[redacted]	Soil PH	Required Temp	Drainage	Soil Texture
[redacted]	5 6-7 5	15-26^{0}C	Perfectly drained	sandy, clay, loamy
[redacted]	6.0-7.5	16^{0}C-27^{0}C	Perfectly drained	sandy, clay, loamy
[redacted]	≤ 7		Perfectly drained	sandy, clay, loamy
[redacted]	5 5-8 0		Perfectly drained	sandy, clay, loamy
[redacted]	5 5-8 5	25-35^{0}C	Imperfect to moderately	water-retaining acidic soils

All of these species can grow in different areas of Pakistan like Rawalpindi, Abbottabad, Mansehra etc Willow needs more amount of water compare to other crops except weeping willow They are ready to harvest after 3-4 years and new shoots will re-grow They can be repeatedly harvested up-to 15 years and can produce 4-5 tones dry wood on average Mostly they are grown at the bank of rivers and lakes because they can protect banks and work as a wind breaker They can also resist against pest and diseases

Requirements for Willow

Technology Required

No particular technology is required to produce willow The cultivation method could be easily taught to former in remote areas

Inputs

Water is the main input needed to produce willow They can grow even on waterlogged areas and convert the area into capable of cultivation of other crops There is no need of fertilizers and nitrogen is taken by the tree from air

Planting Design

The site preparation for willow needs much care They should be grown on double-row fields These rows allow the free movements of agricultural equipment and high density If the willows are grown on long rows almost 4,000-8,000 trees can be planted in one acre It is also recommended that a 20-feet gap should be maintained after every 500-600 feet area along the rows Mostly willow planting is done with un-rooted cutting and the length of cuttings should be 8-10 inches After the end of first season the plants should be cut from the two inches for getting more stems In the second and third season willows can be fertilized for getting more yield After the fourth season willows are ready to harvest and their height is almost 15-20 feet The harvesting can be done any time after fourth season after fallen the leaves

Harvesting

The fallen leaves can add the nutrients in the soil which helps better growth in next season The yield of willow increase in every harvest and to get its full benefit at least seven rotations should be completed In first harvest it gives almost 3 7-5 1 oven dried tons per acre but after two harvests yield increased to 12 tons (Scurlock et al (2000))

Economic Assessment

The plantation and maintenance of willow trees to the harvest time require almost 50,000/- per acre, it includes the cost of plants, their plantation, cuttings of trees and their maintenance The approximately yield of willow is 18 tons of fresh or wet matter If this is sold at the rate of 300/- per maund, then a farmer can earn almost 135000/- per acre in the first harvest season [6]

4.1.2 Bamboo

Bamboo (Bambuseae) belongs to the large woody grasses which has almost 1,250 species Its height varies from 10 cm to 40 meters It is being used as a source of food and fiber in daily routine life 36 million hectares is under bamboo trees globally and in Asia 24 million hectares area is under bamboo cultivation They are grown naturally in tropic and temperate zones of all continents except Europe but mostly cultivated in subtropics regions Only Asia contains its 1,000 species China and India are the major bamboo-producing countries (Scurlock et al (2000)) In 1980s Pakistan imported some bamboo species from China, Sri Lanka, Thai Land and Bangladesh and cultivated on private land

[6] http //pecongress org pk/images/upload/books/8-35-47Short%20Rotation%20Major%20Retd %20Shahnawaz pdf

The planation requirements of these species are,

[redacted]

	Soil pH	Required Temp	Drainage	Soil Texture
	5 5 - 7 5	20^{0}C - 30^{0}C	750-1000 mm	sandy loam soils
	4.5-6 5	22^{0}C - 28^{0}C	1,200-2,500 mm	sandy and clay
	5 0-6 5	27^{0}C-32^{0}C	>1,000 mm	Sandy loam and clay loam

They can be planted in different areas of Punjab, KPK and Azad Kashmir They can also planted in saltwater wetlands especially on the coast of Baluchistan at sonmiani and jiwani

Inputs

They require much feed and even rich soil can be depleted after several plantation so it is better to fertilize the land Green manure, wood ash or chemical fertilizers can be used They grow better under rain conditions They are free from pests and diseases but during first year removing of weeds is necessary

Yield

The yield of bamboo depends on the production of culms in clump They are ready to harvest after five years and at that time mostly it contain six culms per clump After every year the number of culms increased and the culms that are one or two year old should not be harvested In first year of harvest the potential yield is 12 ton per acre with 200 plants per care and 30 ton by planting 1000 plants per acre

4.1.3 Popular

Popular is fast growing short rotated tree having almost 35 species and native to northern hemisphere It was in abundance near the meeting place of public in Roman Empire that is why it is famous as popular tree It is provides almost 20 million m^3 of wood and fiber 91% of popular tree is in natural forests but now it is being planted rapidly Approximately 5 million hectare is under popular plantation and most of it is in China Its plantation requirements are

[illegible]	Suitable	Unsuitable
[illegible]	Loams, Sandy loams, Clay Loams	Very Sandy soil and Summer Flooding Areas
[illegible]	5.5-7 5	Below 5.5 and Above 7 5
[illegible]	380-1,400 mm	Below 380 mm
[illegible]	16^0C -47^0C	Above 47^0C

It can be planted at the bank of River Indus mainly in Punjab and Sindh Rotation cycle is different in various regions but mostly harvesting is done within 6-10 years Its potential yield also varies for rich and poor soils The yield is low in unirrigated and unfertilized areas but high in irrigated land Yield ranges from 1 25-8 61 dry ton per acre

4.1.4 Technology Requirement

The technologies convert the feedstock into heat or electricity with existing technologies that are being used for fossil fuels In this process heat is dominant factor which is generated by these technologies and then converted to some other energy forms Mainly these technologies include Combustion, combined heat and power, Gasification and pyrolysis

a- Combustion

Currently, primary method which is being used to convert the biomass into electricity is combustion or direct firing In this process fuel is burnt into boilers to generate the chemical energy stored in the fuel Any type of fuel can be burned but it is better to burn the fuel which contain less than 50% moisture content If the moisture content is high it should be dried first Mostly the combustion is done on the temperature of 800-1000^{0}C The amount of heat produced by the woods depends on the type of fuel but generally it is estimated that one kilogram of dry wood generate 20 mega joules of energy This method is also used to get energy from fossil fuels like coal but burning wood is carbon neutral because the woods release the same amount of carbon that it has been consumed through photosynthesis In this method biomass is burned in a boiler to produce high pressure steam This steam is used to rotate the turbines that is linked with electric generator which generate electricity (Overend (2004))

b-Combined Heat and Power

Electric power and thermal energy can be generated from a single source efficiently by combined heat and power technology With this technology separate electricity and heat from burning is not required because both can be gained in single step Mostly biomass steam boiler are located in industries or sugar and paper factories where waste heat or steam can be recovered and used for the need of heat in that industry Combined Heat and Power units are more efficient compare to other commercial thermoelectric units because thermos electric units just convert the one third of fuel in o electricity the rest of the heat is wasted in the air which is harmful economically and environmentally The combine heat and power technology convert the more amount of fuel into energy

c-Gasification

Gasification is the process in which biomass is converted into flammable gas through partial oxidation Typically the process is done at the 800-900^{0}C temperature This gas can be used in many energy related applications like it can be burnt directly or converted into electricity This gas also can be used in mix turbines where heat and gas is combined to produce electricity The production of gas through gasification from biomass permits the production of methanol that have the potential to be used as transportation fuel (McKendry (2002))

d-Pyrolysis

Pyrolysis is the process of decomposing the organic matters chemically and turns their some portion into liquids some portion in gas and rest is solid residues comprises ash and carbon The process is done in the absence of oxygen and at the temperature above 430^{0}C The gas produced in pyrolysis needs some additional dealing for the removal of fabric filters and wet scrubbers If flash pyrolysis is used it can convert the biomass into bio-oil with the efficiency of 80% This oil can be utilized in engines and turbines (McKendry (2002))

4.2 Agricultural Energy Crops

The feedstock that contains significant amount of sugar or any material that can be converted into sugar like starch or cellulose can be used to produce ethanol In these days the ethanol which is being traded in the market is sugar or starch based These sugar and starch based crops can be used to produce ethanol The technology which convert the sugar of these crops into ethanol is discussed at the end of this topic These crops are

1 Sugar Crops
2 Starch Crops
   a Wheat
   b Barley
   c Corn

4.2.1 Sugarcane Crop

Sugar crop is long duration (12-15 months) and very important cash crop of Pakistan It is grown mainly for sugar and some other products It is very labor intensive crop Massive amount of labor is required for its plantation and harvesting Its plantation requirements are presented in table 4 4

[redacted]

[redacted]	Suitable	Unsuitable
[redacted]	loams, clayey loams, brown and reddish loams	Very Sandy soil cane
[redacted]	5-7	Below 5 and Above 7
[redacted]	75-150 cm	Below 75 cm
[redacted]	21^{0}C-27^{0}C	Above 47^{0}C

The sugarcane is cultivated in NWFP, Upper Punjab and Lower Sindh 69% of total production is produced in Punjab The average production of sugar crop is almost 55 tons per hectare in Pakistan which is very low compare to other sugar crop producing countries like India and Brazil Ethanol from sugar crop is clean and low carbon fuel which can be blended with gasoline and can also be used pure It is estimated that one ton sugar cane can produce 86 I liter ethanol

4.2.2 Starch Crops

Starch can be converted into sugar by adding some acids and then converted into ethanol Starch is obtained from grains There are many grain crops being cultivated in Pakistan like Wheat, Barley, and Corn

Their plantation requirements are represented in table 4 5

[redacted]

[redacted]	**Soil PH**	**Required Temp**	**Drainage**	**Soil Texture**
[redacted]	6-7	15^0C -26^0C	300 mm	clayey loam soils
[redacted]	6-7	25^0C-40^0C	40-100 mm	clayey loam soils
[redacted]	5 5-7 0	22^0C-30^0C	100 mm	Clay loam to sandy loam

All these crops are being produced in Punjab, Sindh, KPK and Baluchistan 76% of total wheat production is being produced in Punjab and 63% of total corn production is being produced in KPK The average yield of wheat in Pakistan is 1,129 kilograms per acre annually, which are approximately 41 bushels and one bushel can produce 2 7 gallons of ethanol The average yield of barley is 74 bushels per acre and one bushel can produce 2 4 gallons of bioethanol 122 bushels of corn can be obtained from one acre and one bushel of corn can produce 2 7 gallons of ethanol

4.2.3 Technology Requirement

Ethanol from grains can be produce through following two methods

- Wet Milling
- Dry Grind

Wet Milling

In this method grains are soaked in water to make them soft Soft grains are easily separated in various components like starch, fiber and germ To make different products these components are treated separately Starch is used to make ethanol

Dry Grind

In this method all the components are treated together and are separated at the end of process The grain is converted into flour and slurred with water This slurry is cooked and cooled after adding enzymes The yeast is added to make ethanol and by distilling water contents can be removed and the remaining is 95% pure ethanol

4.3 Oil Crops

It is obvious that entire transportation depends on petroleum energies like gasoline, diesel, and liquefied petroleum gas (LPG) and compressed natural gas (CNG) These fossils are being depleted rapidly and world is looking for alternates which can replace these resources viably There are some non-edible oil crops that can be grown on marginal lands means they are not competitor of food crops and their seeds can be used to extract oil That oil can be used for transportation without major modification of engines (Ahmada et al (2013)) Some of these oil crops are

- Jetropha
- Chines Tallow Tree
- Rocket Seed

All three crops can be cultivated on tropical or sub-tropical regions on any kind of soil without great care and fertilizers There plantation requirements are reported in table 4 6

[redacted]

	Soil PH	Required Temp	Drainage	Soil Texture
[redacted]	6.0-8 5	20^{0}C-28^{0}C	300 mm	loamy and sandy soils
[redacted]	5.6-7.5	12.5-30°C	moderate	Clay loam and sandy
[redacted]	7 0-9.0	> 10 °C	moderate	Clay loam and sandy

These oil crops needs less amount of water and even they can cultivated on marginal or waste lands Jetropha has been planted by the PARC Karachi and proved viable in case of Pakistan

Jetropha yield is highly variable in different areas under various conditions It is reported that a single tree can give 0 2-2 0 kg seeds during one year In semi-arid areas yield is approximately 2 0-3 0 ton per hectare, but under better condition of rain fall and soil condition yield can be increased to 8 0 ton per hectare Production yield is also different among individual trees It is also reported that jetropha can give seeds until 50 years (Francis et al (2005))

The average yield potential of Chines Tallow Tree is 14 metric ton seeds per hectare annually Its seed consists of 40-65 % of vegetable oil It is estimated that 2442 liter of oil can be extracted from seed of one acre trees and some time it can reach up to 3673 liter which is higher than other seed oils like soybean, sunflower, safflower and rape seed

Mature plant of Rocket Seed Crop is comprises 20% seed and 80% straw Seeds consists 35% oil content and rest is oil cake Oil cake can be used as animal fodder or burnt to generate heat (Garg and Sharma (2014))

4.3.1 Technology Requirement

The cultivation of jetropha does not require any kind of technology or inputs but for to extract oil from the seeds little machines are required It is generally presumed that sophisticated machines will generate more quantity of oil that is not correct An efficient machine can extract the optimum quantity of oil which depends on the seed

To extract oil from Jetropha seeds simple handmade tools are being practiced in rural areas They are simple and can be practice by farmers They are some other tools which are also being used for extraction of oil Such as

Oil Presses: they are the simple presses used for extraction of oil They are mechanical devices which can be driven manually or can be driven through power The most common press is Bielenberg ram press, which extract oil make oil cakes and soaps It can extract 3 liter oil from 12 kg seeds

Oil Expellers: There are different types of oil expellers which are being used to extract oil from jetropha The most common oil expeller is Sayari oil expeller This is diesel operated oil expeller which was initially developed in Nepal Now it is being used in other countries for oil extraction and preparation of oil cakes Its new version which is driven by electricity is also available in the Market

There are certain modern techniques in the market to extract oil from jetropha and some new methods are also being invented

4.4 Non-Woody Grasses

Short rotation woody crops are ready to harvest within 2-5 years but there are some non-woody grasses that can be harvested on annually basis These grasses are just like solar energy saver that are very easy to plant harvest and process Normally their yield is high as compared to other woody biomass sources They can be grown on number of soils and needs less amount of inputs like diesel, fertilizer and insecticides They can be used in number of energy applications as a solid biomass, cellulosic ethanol and can be converted into pellets Plantation requirements of these non-woody grasses is presented in table 4 7

[illegible]

[illegible]	Soil PH	Required Temp	Drainage	Soil Texture
[illegible]	5 0 or above	Above 16^0C	moderately	Loam and sandy loam
[illegible]	4.5-8 2	25^0C-40^0C	1,500 mm	poorly watered clay soil to extremely watered sandy soil
[illegible]	5 0-8 7	9^0C -30^0C	300-4000 mm	coarse river sandy soils to heavy clay soils

These grasses are being produced in different areas of Punjab, NWFP and Azad Kashmir They can grow on tropic, sub-tropic and temperate regions on many kinds of soil They can be grown on unfertile land even on coarse river sands to heavy clay soils It can be grown on degraded lands, in waste waters or salty lands They can produce 20-30 tons of dry matter per hectare and dry matter of one ton can give 240 litters of ethanol

4.5 Aquatics

The amount of endogenous nutrients in lakes and rivers is rising due to the inclusion of waste water of industrial, agricultural and household activities This water contamination can be controlled by the utilization of aquatic plants The plants that can grow in water, wet soils or on marshy lands have excellent quality to purify the water with little operations These aquatic plants grow rapidly and start decaying if they are not used immedilly, so it cause another pollution But if they are harvested and used as source of biomass can generate an equal amount of energy with terrestrial plants (Jiang et al (2014)) There are two types of aquatics

- Micro Algae
- Macro Algae

4.5.1 Micro Algae

Micro Algae is fast growing unicellular microscopic plant It does not possess roots, stems and leaves They can survive in sever conditions because of their unicellular and simple formation They are not always in green color Their color depends upon the dominant factor in their cells They exist all over the earth There are almost 50,000 species of micro algae but only 30,000 are studied yet Micro algae are of two types, Phytoplankton and Periphyton The former spends their lives in hanged water and the later lives in rocks, residues and plant trunks They can change their internal conditions depending on environment Some algae just consume sun light and convert into chemical energy Some of its species rely only on organic compounds and some other spices ingest both sun light and organic matters

Like other plants they produce oxygen They produce natural oil by converting the water and carbon dioxide in the existence of sunlight They are easily established, can grow with little or no care and consume the water which is not consumable by humans They require almost 49 times less area compare to other biomass oil producing trees for producing same amount of oil Generally they double their biomass within 24 hours They provide feedstock for various type of biofuel like biodiesel, methane and ethanol The biodiesel performs exactly like petroleum diesel by omitting less amount of carbon dioxide (Mata et al (2010))

4.5.2 Macro Algae

Macro algae is multi cellular plant deprived of stem and roots Some of its species can grow in salt water without competing the land and fresh water for agricultural crops They can change their internal system depending on the environment where they are growing Some of its species require more sun light and some needs less

Some of its species can generate more amount of energy compare to terrestrial plants by acquiring less land, for example seaweed can generate 13 1 kilo gram dry weight per meter square annually as compared to sugar cane which produce 10 kilo gram per meter square per annum There are different ways for generating energy from macro algae depending on the form whether they are dry or wet If the algae is dry it can be fired directly or pyrolysis or gasified For using dry energy techniques it has to be dried first In tropical area it can be dried with the sun light which do not require fossil fuels Water evaporates within 2-3 days To use algae at industry level coal-fired boilers are being used to dry the algae which are not economically it's better to dewater the algae before its evaporation

Macro algae can be used in moisture situation by converting in to bio-oil through hydrothermal liquefaction In this process oil is produced from wet algae through pressure and heat in the existence of catalyst The co-liquefaction of micro and macro algae at the temperature of 3400C is best, because it generates less amount of oxygen and more amount of nitrogen Energy can be generated from sole algae or by mixing with other residues through anaerobic digestion like other biomass sources and the residues serve the need of fertilizers (Milledge et al (2014))

4.6 Agricultural Residues

Agricultural residues are capable to act as a sustainable source of biomass They are easily available in abundance at very low cost They are available round the year and they have the potential to serve many types of energy in environmentally positive way The potential of energy which can be generated from the crops residues is given in table 4 8[7]

[7] http //news mongabay com/bioenergy/2006/07/crop-residues-how-much-biomass-energy html

[redacted]

[redacted]	RPR	Heating Value(mj/kg)	Production of Crop (000 tons)	Production of Straw	Potential MWh
[redacted]	0 28	16 01	6,798	1869 45	8,465
[redacted]	2 19	13 45	6,798	14887 6	55,621
[redacted]	2 67	12 46	4,944	13175 8	45,688
[redacted]	1.00	15 46	4,944	4944	21,231
[redacted]	0 20	16 61	67,460	13492	62,250
[redacted]	0 22	12.93	67,460	14504	53,304
[redacted]	3 39	16 21	12,769	43223 1	194,911

RPR= Residue to product ratio, it shows the amount of available residue for each ton produce

Production of straw= Residue ratio multiplied by the amount of crop production

Potential= production of straw multiplied by the lower heating value

From the findings of above model we can conclude that Pakistan has huge amount of agricultural residues Some of these residues are used as a dry fodder like rice husk and rice straw whereas some are used to burn for cooking purpose like cotton sticks, but most of them are burnt in the fields If these are collected and used to convert into bio-fuel, they can provide employment to the number of people and can have positive impact on environment

Cost Estimation of Agricultural Residues

Agricultural residues industry is not developed at all in Pakistan and that is why the value and cost of agricultural residues is not established Mostly the cost of it include gathering and transportation cost as the production cost is covered by the income of original crops Transportation cost depends upon the type of truck, distance of market from the field and bulk density of the agricultural residues

4.6.1 Technology Requirement

Energy can be generated from agricultural residues from number of existing technologies i e they can be directly combusted like other woods, co-fired with coal and can be converted into pellets They can be gasified and pyrolysis technique also can be used by considering the type of residue

4.7 Livestock Manure

Livestock manure is a waste product produced by the animals This waste is recyclable because the nutrient are not fully exploited by the animal There is possibility to utilize these nutrients without paying for them This manure can be converted into biogas with simple technology

4.7.1 Potential

Agriculture is very significant segment of economy of Pakistan, as it adds 21% to Gross Domestic Product and provides employment opportunities to 45% of total labor force in Pakistan

Livestock sector adds 55 9% in agriculture There are 76 8 million livestock (Buffalo and Cow) available in Pakistan which generate approximately 768 million kilogram manure per day According to FAO half of this manure is collected and used as fuel and fertilizers In Addition to that, there are 68 4 million goats, 29 4 million sheep and 932 2 million poultry which also produce huge amount of manure

4.7.2 Technology Requirement

Technology requirement for biogas is simple and easily adoptable Basically it require four necessary elements

- **Organic Matter**

The bacteria that produce biogas take organic matter as food This organic matter is farmyard manure This is the primary source to produce biogas but the amount of gas can be raised by adding some food waste or crops residues

- **Bacteria**

The second necessary element is bacteria These bacteria convert the organic matter into simple acids and then these acids are converted into methane and carbon dioxide by another type of bacteria Normally these bacteria exist in manure and flourish under appropriate conditions

- **Anaerobic Condition**

The third condition of getting biogas from manure is absence of free oxygen Because the metabolisms of the bacteria need oxygen free environment

- **Heat**

The last necessary element is heat Different types of digesters are designed to operate in different temperature Some digesters can heat up by artificial methods

By considering these four elements different types of digesters can be constructed The following types of digesters are available in the market and being used according to the needs and circumstances

Types of Digester

Process of production of biogas with the help of four elements Organic matter, Bacteria, Anaerobic condition and Heat is called anaerobic digestion Almost every type of anaerobic digester perform the same basic tasks They provide the proper conditions for the existence of bacteria to produce methane in the absence of oxygen with the reduction of weed seed, pathogens and odor There are wide range of anaerobic digesters which perform same functions in little bit different way There broad categories are

- Passive System
- Low Rate System
- High Rate System

Passive System

This is the most inexpensive and easily adopted system In this system biogas is added in an existing dealing component and very little control is performed in the reactor environment The best example of passive system is covered lagoon digester

Covered Anaerobic Lagoon Digester: These are the in-ground digesters, which are covered by the moving or flexible air-tight covers For better performance of this type of lagoon it is good to dig two lagoon which should be interconnected Primary lagoon is covered and secondary lagoon is uncovered Primary lagoon can store methane gas and secondary lagoon for waste and contaminated water that can be used for fields Depth of primary lagoon should be as much as possible It will provide best opportunity for the bacteria to survive but secondary lagoon does not require much depth In hot climates small lagoon can work effectively and their seasonal variations are also low But in cold temperature their efficiency not very good and retention period also high The lagoon should be on soil which is sealable through biological action The cover material for lagoon should be ultraviolet resistant, hydrophobic, tear and puncture resistant, non-toxic to bacteria Their manure comprised 0 5%-2% solids Their retention period is 30-45 days or it depends upon the size of digester

Low Rate System

In low rate system animal manure which is added to the digester is the main source of micro-organisms which produce methane Solid retention period and hydraulic retention period is same in this system Plug flow digester and complete mix digesters are the examples of low rate system

Plug Flow Digester: These are the digesters which are loaded with thick manure of 11%-14% solids Mostly their efficiency increase with scrap manure They can be covered by the airtight solid top or by flexible and floating cover The depth of the digester can be 8 feet to 12 feet according to the type of soil The ratio between width and depth should be greater than 1 and less than 2 5 and the ratio between length and width should be from 3 5 to 5 They can work in normal and hot temperature The internal or external heat exchanger can be used to retain the desired temperature in the digester The water in heat exchanger can be warm through biogas boiler The surface of digester can be insulated to maintain the temperature inside the digester For the smooth working of digester its temperature, outflow of the effluent and gas pressure should be examined regularly Their retention time is 12-80 days but a plug flow digester can produce 70% to 80% methane within 15-20 days

Complete Mixed digester: These digesters can be built above or under the ground and made by the concert, steel or fiberglass According to the type of soil and required volume of tank depth can be between 8 feet to 40 feet These digesters contain a mix tank, digester tank, heating and gas recovery system and outflow structure of storage The mix tank work as a control point In that tank situation of manure is adjusted by adding water in dry manure and by adding dry manure in diluted manure Fixed, flexible or floating top can be used to cover the tank but it should be gas tight Their manure comprised 3-10% solids and retention period is 10-20 days To maintain preferred temperature external heat exchanger can be used to mix the feedstock They can operate in mesophilic temperature ranging 95° to 105° F and in thermophilic temperature ranging 135° to 145° F An external or internal heat exchanger can be used to maintain the require heat in tank Insolation can also be used to control the loss of heat The manure in tank is provided on hourly or daily basis and transfer of manure is also done on daily basis For the verification of normal operations in tank heat and temperature should be monitored every day The covers of the tank may be inspected weekly to check the wear and tear and cracks problems Sludge removal should be practiced after 8-10 years

High Rate System

In high rate system solid retention time is greater than hydraulic retention time In this system, to increase the efficiency of digester microbes are confined in the digester Solid recycling, fixed film digester, suspended media digester and sequencing batch digester are the examples of high rate system

Solids Recycling: In this method some of the active bacteria are reimbursed to the digester This decreases the digestion time In plug flow digester microbes and solids are settled in same digester but in complete mix digester solids are established separate and the manure mixture which is rich in bacteria recycled back to the digester

Fixed Film Digester: In this digester maintained media which is made by wood chips or small plastic bags grow methane producing bacteria A thin coating around media called biofilm Bacteria are converted to the digester to maintain the manure level of the digester This also decrease the hydraulic retention time by allowing the construction of small digesters An isolated solid separator is also required to detach the elements from the manure This may reduce the amount of manure

Suspended Media Digester: In these digesters bacteria are hanged in the digester to maintain its flow on rising The flow is maintained in such a way that it allows the exit of smaller particles and retain the larger ones In this type of digester it is tried to keep the microbes in the digester around the biofilm Occasionally some fake media is also used There are two main types of suspended media digester Up flow anaerobic sludge blanket digester (UASB) and the induced blanket reactor (IBR) are the main types of suspended media digesters IBR works better for liquid manure which comprises less than three present of total suspended solids UASB performs better for solid manure which contains six to twelve percent of total suspended solids

Sequencing Batch Digester: Bacteria which produce the methane are retained in the digester Liquids are settled with solids by pouring it In this method digester is fed properly with feedstock then microbes and manure is added to react Solids are settles and effluent is withdrawn This process has to be repeated five times in a day for the regular gas recovery The retention period is just five days This works well for liquid manure and if the bacteria id added in the digester at the starting of the process this can work even for the complete soluble organic matter

4.7.3 Technical Assistance

The development of biogas plant were started with the efforts of individual, the first biogas plant was set up in Sindh in 1959

Government of Pakistan has propagated the biogas technology in the star of 1976, with the target of installation of 1200 biogas units The units were constructed with steel material, but they could not succeed due to limited life time of unit and daily filling of manure

In 1986, Director General, New and Renewable Energy Sources (DGNRER) and Ministry of Petroleum and Natural Resources introduce a scheme to set up 4000 biogas plants In this scheme 100 biogas plants were constructed with 100% subsidy by the Federal Government 50% of remaining plants were constructed with 50% subsidy on second phase and subsidy was removed from the construction of remaining 50% plants on third phase but the technical assistance was provided [8]

In 2000, Bio Gas Support Program was started with the help of Government of Pakistan and 1200 biogas plants were installed of household size and the results were not much satisfactory

In 2007, Pakistan Council of Renewable energy Technologies (PCRET) set a target of 2500 biogas plants with the subsidy of Rs 17000/- per unit In two years 2,000 plants were established but again the problem was steel material of digesters

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[8] http //www ciitlahore edu pk/erc/ERCWP/ERC-WP-14 pdf

Up to May 2009, Pakistan Dairy Development Company (PDDC) set a target of 450 biogas plants but due to the positive response of the customer the number of plants increased to 556 in July 2009 The cost of these plants was ranging from Rs 35,000 to Rs 40,000 and 50% subsidy was also provided by the PDDC

In 2010, Rural Support Program Network (RSPN) took initiative to develop the domestic biogas program The program was developed with the cooperation of Government, non-government and private sector Within the time frame of four years 5000 doom type digester made by bricks and cement were constructed and 500 masons were trained [9]

4.7.4 Output Estimation:

According to Pakistan Economic Survey (2014-15) there are 76 8 million livestock (Cows and Buffalos) in Pakistan A medium size animal produce 10 kg of manure daily on average So, these livestock can generate 768 million kilogram manure daily If it is assumed that half of the fresh manure can be collected daily then there is possibility of the availability of 384 million kilogram animal dung on daily basis Approximately 19 2 million cubic meter biogas (at the rate of 05 m^3 per kg of animal dung) can be produced with this amount of manure Total population of Pakistan is 188 02 million and 70% of this amount that is around 134 197 million resides in rural areas From this rural population we can fulfill the cooking needs of 29 26 million of rural population can be fulfilled by 19 2 million cubic meter biogass

[9] http //nation com pk/editors-picks/11-Jan-2015/biogas-future-of-punjab

4.7.5 Economic Impact

Biogas is methane rich gas which has the ability to replace the all petroleum, deiseal and electricity in the rural areas of Pakistan As one cubic meter biogas is equal to 6 4 KWh and one litter oil is equal to 10 KWh So it means that one litter diesel oil is equal to 1 5 cubic meter of biogas (Ahmad (2010)) A biogas consumer family containing 8-10 members can save about Rs 3,000 which they spend on cooking and generated bio-fertilizer is an extra advantage For 8 cubic meter biogas plant the manure of three buffalos is sufficient and the investment of 65,000 rupees is required which is recoverable within 15 months Biogas increase the monthly income of rural farmers by saving their expenditures from chemical fertilizer, cooking and lighting fuel It's also reduces their medical bills

The feedstock and material for construction of plant of biogas is locally available, so it increases the number of employees and demand of bricks and cement companies It causes an increase in production and employment of the country This ultimately results high economic growth (Apergis and Danuletiu (2014)) (Khurshid (2009))

4.7.6 Environmental benefits

Biogas energy is carbon neutral and it produces less amount of carbon dioxide (CO2) compare to conventional sources of energy as 1KW of electricity from biogas decrease 7 kg of CO2 annually (Ali et al (2013)) Converting animal dung into biogas through anaerobic digestion can mitigate the odor up to 70-97% and pathogens up to 99% (White et al (2011))

In the process of manure to biogas total amount of ammonia is saved and dissolved amount is increased by 10-15% Animal manure comprises some pathogens or viruses that are harmful for human and animal health but when manure is converted into gas, it becomes almost free of these viruses

Animal manure contain ample amount of weed seeds that have the potential to grow even after passing from animal stomach but when it is used to generate gas these weed seeds lost their growing ability up to 99% and then they are best fertilizers for the soil (Minde et al (2013))

4.8 Municipal Solid Waste

Municipal solid waste comprises solids, semi-solids and non-soluble materials According to Ministry of Finance (1996) the amount of solid waste in Pakistan was estimated between 0 283-0 612 kg per capita on daily basis and increasing at the rate 2 6% annually According to Economic Survey of Pakistan (2014-15), population of Pakistan is 188 02 million If we apply growth rate of waste generation annually and calculate municipal waste amount generated in 2014 we can get 173 79 million kg on daily basis This waste is being dumped in landfills which causes many environmental problems The amount of waste generated and reached to the landfills depends on the system of waste management In Pakistan all the waste is not reached to the landfills which pollute the air, water and soil If there would be a proper waste management system this waste can be used as a source of biomass after separating the recyclable material The heat value of solid municipal waste is estimated 6 89 MJ per kilogram

4.8.1 Technology Requirement

Before converting the waste into energy, it is preferable to separate the recyclable and hazardous waste from the municipal solid waste There are number of technologies which are being used to convert the biomass sources into energy Biogas can be generated from municipal solid waste through anaerobic digestion The techniques which are being used to convert municipal solid waste into energy other than anaerobic digestion are

Incineration: This technique is used to convert the waste into energy, the mass burn incineration is preferable best option as it does not require extra labor to separate the metals and hazardous waste from municipal solid waste

Gasification: It is a process in which the components of waste are separated at high temperature into oxygen-starved reactors This process is also being used for mix waste and syngas is established in this process which consist of methane, carbon dioxide, hydrogen, carbon monoxide and water vapor

In this chapter we have analyzed the potential and the harnessing requirements of different sources of biomass It can be concluded that Pakistan has more than enough potential of biomass sources and almost all sources are exploitable by using the inputs available within the country Most of the resources do not require any inputs but some of them require some techniques and tools to convert these resources into fuels It can also conclude that simple unskilled labor can also participate in exploitation of biomass sources The exploitation of these resources can have positive impacts on environment and economic growth

Chapter 5

Results and Discussion

5.1 Model Specification

The second objection of the research was to analyze the impact of renewable energy on economic growth In the past researchers used the different models to investigate the determinant of economic growth There is not a single and specified model which is used to determine the economic growth We select encompassing methodology to avoid the missing variables bias which was not considered by the previous studies We have selected one basic growth model and three models used for Pakistan economy

Model: 1

The following model is based on Branson 1988 This is augmented version of Solo production function augmented for energy use

$$Y = AL^{\alpha} K^{\beta} E^{(1-\alpha-\beta)}$$

To analyze the differential impact of renewable energy used, a slightly modified version of the above equation We differentiate the energy into renewable and non- renewable, therefore equation takes following form

$$Y = AL^{\alpha} K^{\beta} Cre^{\gamma} Er^{\delta} En^{(1-\alpha-\beta-\gamma-\delta)} \qquad (1)$$

Taking Log transform

$$\ln y = \ln(a) + \alpha \ln(l) + \beta \ln(k) + \gamma \ln(Cre) + \delta \ln(Er) + (1 - \alpha - \beta - \gamma - \delta) En + \varepsilon$$

Where Y represents total output, L labor, K capital, A total factor productivity, Cre combustible renewables and waste, Er Electricity Production from renewable resources and En Electricity Production α, β, γ *and* δ are the output elasticity's of capital, labor and energy, respectively These values are constants determined by available technology

Model: 2

Shahbaz et al (2008) estimated the economic growth of Pakistan by using the following model

$$GDPR = \beta_0 + \beta_1 FD + \beta_2 FDI + \beta_3 REM + \beta_4 TR + \beta_6 INF + \varepsilon_t \qquad (2)$$

Where, GDPR represents GDP per capita, FD is financial development proxies by the credit to private sector as share of GDP, FDI is financial openness proxies by foreign direct investment share of GDP, REM is foreign remittances received % of GDP, TR is trade openness which is calculated by dividing the total trade by GDP and INF is annual inflation

Model: 3

Rehman and Slahauddin (2010) estimated the economic growth in Pakistan for the period of 1971-2006 with annual data by using the following model

$$LGNPPC = \beta_0 + \beta_1 MC + \beta_2 LFD + \beta_3 LFNFD + \beta_4 INFR + \beta_5 LFDI + \beta_6 LLTR + \beta_7 LSTL + \varepsilon_t$$

(3)

Where *LGNPPC* represents Log of real GNP per capita, MC is market capitalization measured by total capital as share of GDP, LFD is log of financial development measured by the credit available to the private sector as share of GDP, LFNFD is log of financial instability measured by the standard deviation of inflation rates, INFR is inflation rate which is calculated by subtracting the previous year consumer price index from current year consumer price index and then divided by previous year consumer price index, LFDI is log of foreign direct investment as share of GDP, LLTR is log of literacy rate measured by the ratio of primary completing population to total population, LSTL is log of stock market liquidity measured by the stock traded as share of GDP

Model: 4

Shahbaz and Feridun (2011) has checked the long run relationship between economic growth and electricity consumption in case of Pakistan

Their model was

$$\Delta \text{LGDP} = \beta_0 + \beta_{1t} + \sum_{i=1}^{m} \beta_2 \Delta LGDP_{t-i} + \sum_{i=0}^{m} \beta_3 \Delta LEC_{t-i} + \beta_4 LGDP_{t-i} + \beta_5 LECT_{t-i} + \varepsilon \qquad (4)$$

Where,

LGDP represents Log of Gross Domestic Product and LEC represents Log of Electricity Consumption

The models M1, M2, M3 and M4 are estimated through Ordinary Least Square (OLS) and their Standard Error (SE) are given in the following table

[redacted]

	Name	SE
[redacted]	M1	1 10159
[redacted]	M2	1.49843
[redacted]	M3	1 36559
[redacted]	M4	1.37375

From above table, it is evident that M1 has the smallest standard error Null hypothesis which is

$$H_0(1) \text{ M1 encompass Mi}$$

Is tested against M2, M3 and M4 The results of encompassing test are given in following table 5 2

[redacted]

	Sargan	
[redacted]	stat	P-value
[redacted]	10 726	0 3792
[redacted]	15 348	0 3548
[redacted]	7 8335	0.4499

Where * and ** signifies significance level at 5% and 1%

The results of table 5 2 imply that M1 encompasses the remaining models i e production function including energy with its parts In other words we can ignore models M2, M3 and M4 So in our final model the variables of M1 i e Labor Input, Capital Input, Combustible renewable and Waste (% of total energy) Electricity production from renewable sources (KWh) and Electricity production (KWh) are included This model offers better explanation of growth than many other models The encompassing helps us to select the following model

$$\ln y = \ln(a) + \alpha \ln(l) + \beta \ln(k) + \gamma \ln(Cre) + \delta \ln(Er) + (1 - \alpha - \beta - \gamma - \delta) En + \varepsilon$$

5.2 Testing for the stationary

To check the stationary properties of variables, Augmented Dickey-Fuller test is applied Level and bounded serious are separated and drift and trend are added where necessary The results are given in table 5 4

[redacted]

[redacted]	Test Statistics	Lag	t-adf	I(d)
[redacted]	None	0	-1 032	I(1)
[redacted]	Constant	2	-1.586	I(1)
[redacted]	Constant	2	-1 879	I(1)
[redacted]	Constant	2	-3 015*	I(0)
[redacted]	Constant	2	-1 633	I(1)
[redacted]	Constant	2	-2 951	I(1)

All the variables in our final model including dependent and independent are tested for the order of integration Optimal lag length is selected on the basis of minimum AIC, it is evident from the table 5 4 that five series out of six has unit root So in order to avoid the spurious regression it is necessary to check the co-integration Before checking the co-integration among the series, checking of unit root in residual series is also necessary If the residual series is stationary and value is negative, it means co-integration exists

[illegible]

	Test Statistics	Lag	t-adf	I(d)
[illegible]	None	0	-4 841**	I(0)

Where ** signifies significance level at 5% and 1%

The result shows that error term is stationary so we can conclude that long run relationship exist among the variables

5.3 Long Run Relationship

The above model is estimating by using OLS and results are given in table 5 3

[illegible]

	Coefficients	Standard Error	P-Value
[illegible]	340.643	175 5	0 0624
[illegible]	-12.7932*	5.034	0 0169
[illegible]	4 88098	3.115	0 1283
[illegible]	-0.680825	0 4550	0 1458
[illegible]	8 67361*	3 245	0 0124
[illegible]	-9 91831	5 454	0 0797

Where * and ** signifies significance level at 5% and 1%

The coefficients and standard error of the independent variables are given in Table 5 3 The results reveals that the capital input and electricity from renewable energy sources are significant on 5% level of significance According to results capital input is negatively associated with growth means increase in capital causes decline in growth because of convergence hypothesis, whereas electricity production from renewable energy sources positively associated with growth means increase in electricity production from renewable energy sources leads to increase in growth Combustible renewable energy and electricity affects negatively growth and growth in labor effects positively but all these three variables proved insignificant

5.4 Short run relationship

Error correction model is used to find the short run and long run relationship between growth rate and independent variables which are Capital, Labor, Combustible renewable energy, Electricity production from renewable energy sources and electricity production First difference of all series is taken and the results are given in following table

[illegible]	Coefficient	Std Error	t-value	prob
[illegible]	-1 43786	0 8652	-1 66	0 1086
[illegible]	0.155828	4.265	0.0365	0 9711
[illegible]	26 4650	25 57	1 04	0 3102
[illegible]	-0.920485**	0.3238	-2 84	0.0086
[illegible]	4 53800	3 047	1 49	0 1485
[illegible]	-2 68716	7.297	-0 368	0 7157
[illegible]	-1 08849**	0 1637	-6 65	0 0000

1.25985	Mean (DGR_Y) 0 0377825
0.680542	No of parameters 7
32	Durbin Watson stat 1 73
-50.514	Var (DGR_Y) 3.91457

Where ** signifies significance level at 5% and 1%

The coefficient of ECM is negative and significant, which means the model is in equilibrium in long run From the results we can conclude that capital labor and electricity from renewable energy is positively associated with growth in GDP, means increase in these variables will lead to increase in growth in GDP Combustible renewables and waste and electricity production are negatively linked with growth in GDP These variables do not affect the growth in short run but they have impact in long run In presence of energy other variables except capital input possess no explanatory power The separate estimation of these variables may give significant results

Chapter 6

Summary of Findings, Conclusion and Recommendation

6.1 Summary of Findings

The objectives of this research is to explore the potential of biomass resources and to investigate the impact of renewable energy sources on economic growth The research has been divided into two parts In the first part overview of biomass resources is presented and in the second part impact of renewable energy on economic growth is analyzed It is found that Pakistan has huge potential of almost all types of biomass resources Exploitation of these resources is not compatible with other food and agricultural products Most of these resources are considered as a waste and being dumped or burned to get rid of them

The exploitation of biomass resources is found feasible and renewable energy has positive and significant impact on economic growth

Many oil crops like Jetropha, Chines Tallow tree and rocket seed crop can be grown on marginal and barren lands They can be grown without any fertilizers and pesticides Their seeds can be crushed easily with any seed crushing machine The jetropha oil is tested and found feasible for use as a jet fuel The seeds are not useable for human beings because of bitter taste

Short rotation energy crops can also be planted on wet land and at the bank of rivers and lakes They do not only serve as fuel but also control soil erosion and strengthen the banks Because of being short rotated they are easily replaced and do not reduce the forests Similarly non-woody grasses can be grown on empty lands Most of these grasses are grown for dual purposes, in early season they are used as fodder and lately used as biomass

Mostly these grasses are grown on tropic areas needs less inputs and can be harvested until 10 years without replantation These grasses are known as solar energy collector and produce five times more energy than they take to grow The agricultural residues which are being burnt in the fields that is neither fine for atmosphere nor for the field itself and have the potential to be served as an energy purpose

Managing municipal solid waste is also a great trouble for developing countries but that is better in producing bio gas compare to livestock manure Different types of aquatics can transform the polluted water into consumable by the plants and animals with producing fuels Livestock manure is also the biggest source of bio gas and can generate 19 2 million cubic meter bio gas on daily basis The plantation, management and require technology of these resources is also analyzed and found feasible for Pakistan

To find out the impact of renewable energy sources on economic growth encompassing methodology is adopted Spurious regression is avoided through unit root testing and Engel and Granger co-integration test The model which included the variables of electricity from renewable energy sources and combustible renewables and waste was found final model Combustible renewables and wastes is negatively associated with economic growth in short run and statistically significant Whereas the variable of electricity production from renewable sources was found positively associated with economic growth and statistically significant in long run

6.2 Conclusions

Pakistan is agricultural and energy deficit economy Biomass is directly linked with the agriculture and can also help to increase the economic growth The reduction in imports of fossil fuels will lead to decrease in import bills and circular debt, because all the sources of biomass are in abundance and can be easily exploited

The concept of renewable energy is not new but it has gained the special attention after the Kyoto Protocol[10] and Peak Oil Theory[11] On the one side there is danger of their depletion and on the other side they are badly affecting the environment So, the sustainable development eagerly demand the exploitation of renewable energy sources The technology require to exploit these resources is very simple and can be easily taught to the farmers and other villagers For example the construction of digesters is easy and require simple labor The construction material is also locally available This will lead to generate the new opportunities of employment and will reduce the burden of imports and unemployment Thus, energy from renewable sources not only can electrify the remote

[10] The **Kyoto Protocol** is an international treaty, which extends the 1992 United Nations Framework Convention on Climate Change (UNFCCC) that commits State Parties to reduce greenhouse gases emissions based on the premise that (a) global warming exists and (b) man-made CO_2 emissions have caused it

[11] Peak oil, an event based on **M King Hubert**'s theory is the point in time when the maximum rate of extraction of petroleum is reached after which it is expected to enter terminal decline

villages, provides fuel for vehicles, manages the agricultural waste and municipal waste in an efficient way but also improve the economy

The use of biomas for cooking purpose instead of fire woods and dungs can decrease the health issues of women and save their time The systematic exploitation of biomass sources will improve the environment condition by reducing the carbon dioxide omission

Impact of renewable energy on economic growth is also proved empirically The neighboring countries having same geological and geographical situations are far ahead in harnessing the biomass resources

6.3 Recommendations

On the basis of the results of this research, we can have a clear idea about the theoretical potential of biomass resources whereas, the impact of renewable energy sources on economic growth is found empirically It is also evident through literature that neighboring countries are in better position than Pakistan There should be more researches and developments on the harnessing method and technology of these resources The authorities should take robust and serious actions to harness all sources of biomass not only livestock manure A comprehensive policy is needed to utilize all these resources considering their types and possibility

There is 88, 76,333 acres as culturable waste land in Pakistan which can be utilize to plant the oil crops, non woody grasses and some short rotation energy crops The utilization of this land will increase the energy production with increasing the employment opportunities in Pakistan

The need of gas in villages can be fulfilled through bio gas and biodiesel can be used for transportation The biogas digesters can be constructed on landfill areas and the dumped waste can be utilize to produce gas instead of polluting the area This gas can be transferred to any nearest grid station to produce electricity The saved gas from house hold consumption and transportation can be provided to industries Different types of aquatics can be planted in polluted lakes and rivers by the industries chemicals These aquatics can purify the water which is useable for plants and animals' and aquatics can be harvested to serve as a source of biomass Thus, energy from renewable sources not only can electrify the remote villages, provides fuel for vehicles, manages the agricultural waste and municipal waste in an efficient way but also improve the economy Therefore, slight subsidy on awareness campaign of renewable energy can shed light on the problem of energy crises which leads to the active work and effort for it which in result will overcome energy crisis

The study has provided the overview of biomass resources It could be in more detail and depth but due to the constraint of data the empirical analysis of all biomass resources could not be done

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