Biomass to Bioenergy – A Market Analysis of Pakistan

By

Zulfiqar Ali

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Session 2017-19

Supervised by

Dr Rabia Liaquat

A Thesis Submitted to the US-Pakistan Center for Advanced Studies in Energy in partial fulfilment of the requirements for the degree of

MASTERS of SCIENCE

in

Thermal Energy Engineering

US-Pakistan Center for Advanced Studies in Energy (USPCAS-E)

National University of Sciences and Technology (NUST)

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THESIS ACCEPTANCE CERTIFICATE

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Certificate

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Abstract

Bioenergy currently is the largest source of renewable energy worldwide. In Pakistan, modern bioenergy is not utilized to its full extent. If utilized fully, bioenergy can help Pakistan become secure in terms of energy, add to economic development and help in mitigating climatic changes. Being carbon neutral, bioenergy can help achieve Pakistan's intended nationally determined contribution in the United Nation's Conference of Parties (COP) 21. However, to realize such goals there is a need understand the underlying situation of the bioenergy market of Pakistan and policy development to pave way for a sustainable bioenergy deployment, without endangering food security, land usage, biodiversity, and water resources. To better understand the bioenergy market of Pakistan, this study aims to analyze and evaluate the recent bioenergy policies in the first part. For analysis and evaluation, frameworks have been developed, which can be used in the future as well in analyzing the policies and gauging their impact on bioenergy development. The second part of the research work performs comprehensive strengths, weaknesses, opportunities and threats analysis of the bioenergy generation in Pakistan. To substantiate the results of SWOT analysis a questionnaire was shared with stakeholders in the energy sector. The study found that the policies over time have improved and different incentives are provided to investors in the bioenergy sector, still, there are internationally proven policy options that are not being adopted by policymakers in the country. Secondly, the development of bioenergy in the last two decades is encouraging but the contribution to the overall energy mix is a very small fraction. Moreover, the SWOT analysis concluded that bioenergy potential is the greatest strength, and weaknesses include lack of infrastructure. The analysis has been compared with the opinion of energy experts to substantiate objectivity of analysis. It was found out that expert had a similar opinion with that of the analysis. Furthermore, the study suggests concrete recommendations for future considerations to enhance the efficacy of policymaking and bioenergy deployment in Pakistan.

Keywords: *Bioenergy Market, Bioenergy Policy, Bioenergy Policy Evaluation, Pakistan*

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Zulfiqar Ali, Rabia Liaquat, Asif Hussain Khoja. *"A comparison of Energy Policies of Pakistan and their impact on Bioenergy development"*. Energy Policy, (Under Review).

List of Abbreviations

AEDB	Alternative energy development board
AREP	Alternative and renewable energy policy
CDM	Clean development mechanism
DGNER	Directorate general of new and renewable resources
ECC	Economic coordination committee
EIA	Energy information administration
FIDA	Foundation for Integrated Development Action
ICB	International competitive bidding
IEA	International energy agency
IPP	Independent power producer
NBM	National biofuel mission
NEPRA	National electric power regulatory authority
NGO	Non-governmental organization
PCAT	Pakistan council of appropriate technology
PCRET	Pakistan council of renewable energy technologies
PDBP	Pakistan domestic biogas program
PDDC	Pakistan dairy development centre
PEI	Policy effectiveness index
PPIB	Private power infrastructure board
PSDP	Public sector development program
RET	Renewable energy technology
RSPN	Rural support program network
SWOT	Strengths, weaknesses, opportunities, threats
TOE	Tones of Oil Equivalent

Chapter 1 Introduction

1.1 Background of the Study

Energy is one of the basic drivers of the modern economy [1]–[3]. With an increase in industrialization and standards of living, the demand for energy is increasing. According to the International energy agency (IEA)'s World energy outlook 2018 [4], demand for primary energy will increase by almost 40% by 2040 compared to demand in the year 2017. While energy is critical for economic development and wellbeing but at the same time, all forms of energy generation have externalities associated with them that threaten the same well-being [5]–[7]. Therefore, to mitigate the effects of using conventional energy sources the world is moving towards renewable energy sources [1], which have a lower carbon footprint and externalities associated [8]. To put it into perspective, IEA [4] estimates that business, as usual, would lead to global CO_2 emissions of 42.5 gigatons by 2040, which is 30% more than the emission levels for the year 2017. Whereas, new policy scenario, where renewables share a small part in energy generation, there will be CO_2 emissions of 35.9 gigatons by 2040.

Though there are multiple renewable energy sources, biomass is one of the oldest and widely used renewable energy resource [9]–[11]. According to IEA, for the year 2017, biomass supplied 1384 MTOE (Million tons of oil equivalent) of energy globally as compared to a total of 607 MTOE by the rest of the renewables combined. Though there are different routes for bioenergy generation from biomass, direct combustion remains the most popular way of conversion. Direct combustion of biomass, which includes fuelwood, animal dung, forestry and agricultural residue, is the primary way of energy generation among rural communities in developing countries [12]. Whereas, modern bioenergy conversion techniques include anaerobic digestion, fermentation, transesterification, pyrolysis, and gasification. For the year 2017, the traditional use of biomass for bioenergy accounted for 658 MTOE and modern bioenergy accounted for 727 MTOE globally. In terms of location, the Asian continent leads with 38% of world bioenergy supply, followed by Africa with 29%, Americas 18%, and Europe with 13% [13]. Whereas, in terms of modern bioenergy utilization, the Americas and Europe take lead. American continents produce more than 70% of the world's biofuels, while, Europe produces 53% of world biogas. Among world countries, Brazil, China, the United States and India are leading in terms of bioenergy generation [14].

Pakistan is a developing country with an agrarian-based economy. Pakistan generates a large amount of biomass annually. Most of this biomass is in the form of agricultural residue and municipal waste. According to the Biomass atlas of Pakistan [15], a joint project of the World Bank and Alternative energy development board (AEDB), total agricultural residue generation from five main crops of Pakistan stood at 139 million tons. Which according to some study is enough to generate 519 TWh of thermal energy. An estimate made by A. Raheem et al. [16] for the potential of biogas generation from municipal solid waste from ten of the largest cities of Pakistan stood at 242 million cubic meters per day. While the potential for biogas generation from livestock manure was put at 11,250 million cubic meters per day [16]. Though the potential of bioenergy generation is very high, the utilization rate remains dismally low. According to National electric power regulatory authority, a total of 785 GWh of electricity was produced from bioenergy resources, which included sugarcane bagasse only. This represented only 0.65% of the total electric energy generation in 2017 [17].

Pakistani government over the years has undertaken several initiatives for bioenergy dissemination among its population but most of them failed to attract public attention towards bioenergy [18]. Though a comprehensive renewable energy policy was promulgated in 2006, it took another eight years to inculcate bioenergy into the scope of the same policy. The government of Pakistan is currently in the process of promulgating a new renewable energy policy named ‘Alternative and renewable energy policy of Pakistan' (AREP 2019)’. Despite the presence of such policies and initiatives, the only worthwhile sector that currently provides with bioenergy is the sugar industry. Which utilizes sugarcane bagasse to produce electricity. For the rest, there is an absence of provisions for the utilization of indigenous biomass resources. There remains untapped bioenergy potential to be exploited for use in the power, heat and transport sector.

1.2 Problem statement

The share of modern bioenergy in the primary energy supply of Pakistan is a paltry fraction of the total supply [19]. Though in the process of promulgation, the upcoming AREP 2019 is about to set a bold target of achieving 20 per cent total energy supply from renewable energy sources by 2025 and 30 per cent by 2030. Apart from setting targets, the AREP 2019 is silent on how to achieve such a humungous share in total energy supply. Thus, it can be assumed that along with other renewable energy resources like solar and wind, bioenergy will have to contribute a significant part to realize the target set in the policy. While energy conversion technologies for solar and wind are mature enough to be commercialized, there remains work to be done in the case of bioenergy technologies. Secondly, Pakistan doesn't have a strong industrial base to develop and deploy modern bioenergy technologies.

Therefore, there is a need to understand the underlying problems and challenges that hamper the development of the bioenergy market in Pakistan. Secondly, there is a need to understand the nature of challenges that hamper the development of bioenergy, both through a top-down and bottom-up study of the bioenergy market.

1.3 Research objectives

1. To propose a framework for energy policy analysis and evaluation of its effectiveness in bioenergy development.
2. To apply the framework to analyze and evaluate the current policy situation in Pakistan.
3. To do a SWOT analysis of the bioenergy generation of Pakistan.

1.4 Scope of the Research

The basic biomass feedstock considered in this research is of agricultural residue only. Other biomass resources like forestry residue, municipal waste, industrial waste, energy crops, and algae are of secondary interest in this study. The study analyses and evaluates the energy policies of Pakistan for its impact on the bioenergy development of Pakistan. After considering the policies for their strengths and weaknesses, a comprehensive SWOT analysis is done for the bioenergy sector of Pakistan. Though the study has tried to analyze the most important factors of the bioenergy market, there are limitations associated with the study. This research doesn't represent a comprehensive economic study, to do so would require far greater analysis of aspects such as the capital costs, operating and maintenance costs, and other financial parameters like debt and equity payment, taxes and inflation impacts. The environmental impact quantified in this study includes GHG reductions associated with final bioenergy use, it doesn't compute complete life cycle emissions associated with biomass to bioenergy conversion. Whereas for future studies in the sector, this study will provide valuable information on the policy situation and the current state of the bioenergy market in Pakistan. The policy analysis and evaluation method can prove helpful for future policy studies, within and outside the country. Whereas, the SWOT analysis will leave a foundation on which the investors and policymakers in Pakistan can work to build a sustainable bioenergy sector.

1.5 Research Organization

This study is organized in the following manner. Chapter 1 introduces the background of the study, problem statement, and the scope of the research work. Chapter 2 reviews the literature for global bioenergy market, previous biomass and bioenergy market studies of Pakistan. Furthermore, a comprehensive review of recent energy policies is done with respect to bioenergy. Chapter 3 discusses the methodology of the study, including models and methods used to evaluate and compare bioenergy policies and SWOT analysis. Chapter 4 provides with results of the study and discusses them, along with recommendations for bioenergy policy development and implementation in Pakistan. Chapter 5 winds up the study with conclusions.

1.6 Thesis flow

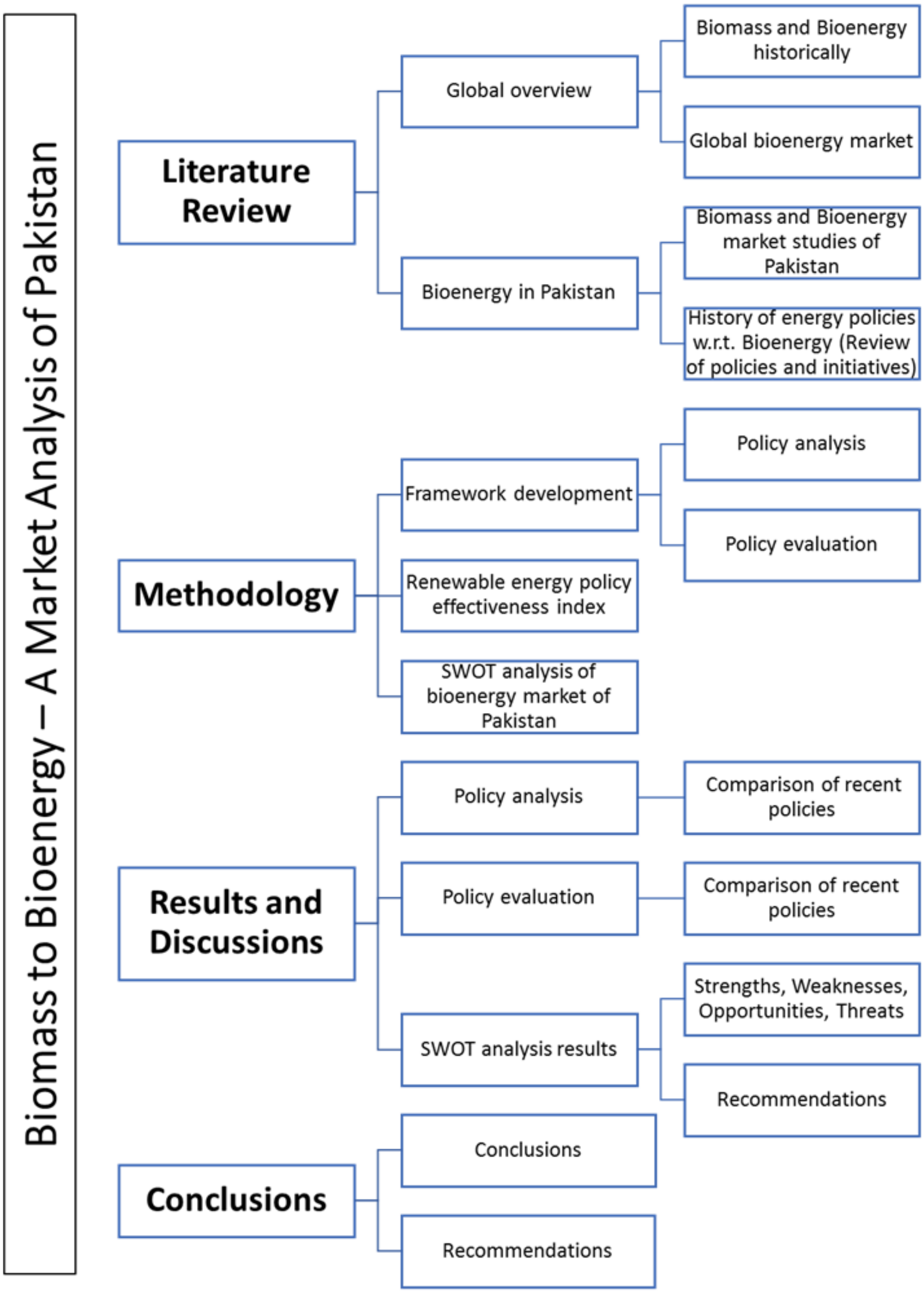

Figure 1.1 Thesis Flow

Summary

This chapter introduced the topic taking the reader from a global perspective to the local perspective in terms of bioenergy markets. Globally bioenergy is a major contributor to the final energy consumption, same being the case for Pakistan as well. Which is partly due to the lack of access to modern energy fuels which are primarily based on fossil fuels. There remains a huge untapped potential of bioenergy in Pakistan, which through proper planning and execution can help the country in energy security, increasing economic activity, employment generation and reduced reliance on foreign energy imports. The three main objectives for this research are enlisted here, which are to propose a framework for energy policy analysis and evaluation of its effectiveness in bioenergy development, apply the framework to analyze and evaluate the current policy situation in Pakistan and to do a SWOT analysis of bioenergy market of Pakistan. Then the scope for this study was discussed. The scope biomass feedstock considered in this research is of agricultural residue only. Other biomass resources like forestry residue, municipal waste, industrial waste, energy crops, and algae are of secondary interest in this study. The study analyses and evaluates the energy policies of Pakistan for its impact on the bioenergy development of Pakistan. After considering the policies for their strengths and weaknesses, a comprehensive SWOT analysis is done for the bioenergy sector of Pakistan. The chapter is concluded by discussing the organization of the study and with the provision of graphical flow for the work done.

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Chapter 2 Literature Review

2.1 Biomass and Bioenergy historically

Biomass refers to the materials obtained from a living or recently lived biological organism, which includes both plants and animals [1]. Whereas, the energy generated from biomass is called bioenergy [2]. Wood which is the first energy source used by mankind is a type of biomass [3]. Biomass remained the major source of energy until the advent of the steam engine in the 17th century. By 18th century coal became a major energy source and by 20th century petroleum-based fuels took over as major energy sources in the world [3], [4]. Currently, fossil fuels provide 80 per cent of the world's energy demand, out of which Oil stands at 38%, Natural gas at 21% and Coal at 21% [5]. Whereas biomass provides 13% of total energy consumption globally and rest is provided by other renewables i.e. 7%.

The presence of large fossil fuel dependence is due to the attractions they provide like high energy density and ease of transport [6]. But there are negative externalities associated with emissions from fossil fuels. One of the major repercussions is the global climate change and temperature rise [7]. Which led the United Nations to adopt the first Framework convention on climate change (UNFCCC) in 1992, which has been ratified by multiple countries [8]. While the convention has been improved over time to meet the changing global circumstances, the major objective remains the same. Which is to "stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" [9]. Therefore, an emphasis on renewable energy sources has increased since the first UNFCCC.

Biomass being one of the renewable energy sources provides a way to quench the thirst for energy in the modern world and help mitigate the deteriorating global environment [1]. Biomass offers a short production period and formation of fuel and it is the only renewable energy source that has the ability to absorb Carbon dioxide from the atmosphere, which is one of the major greenhouse gasses causing global warming and climate change [8], [10], [11].

2.2 Global bioenergy market

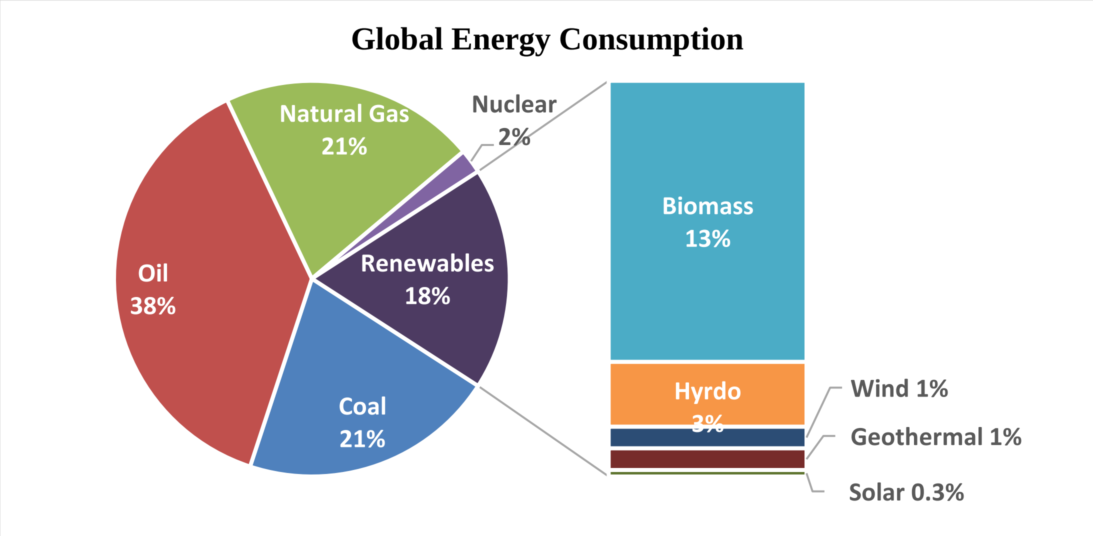

Figure 2.1 Global Energy Consumption (IEA 2017)

World today is more dependent on fossil fuels for fueling the wheels of the modern economy than in the entire history of mankind. According to the International energy agency's estimations [5], the world consumed a total of 367 EJ (Eta joules) of energy in the year 2017. Of the total 367EJ, fossil fuel contribution was 80 per cent. Renewable energy consumption stood at 18 per cent of the total. Figure 2.1 represents the global energy consumption, according to the source of energy for the year 2017. Biomass leads the renewable energy sources with a contribution of 13% towards global energy consumption, making it the fourth-largest energy source globally. Biomass is followed by other renewables including, Hydro (3%), Wind (1%) and Geothermal (1%) [12]. Figure 2.2 presents and compares the consumption of different types of renewable energy sources globally, from the year 2000 to 2017.

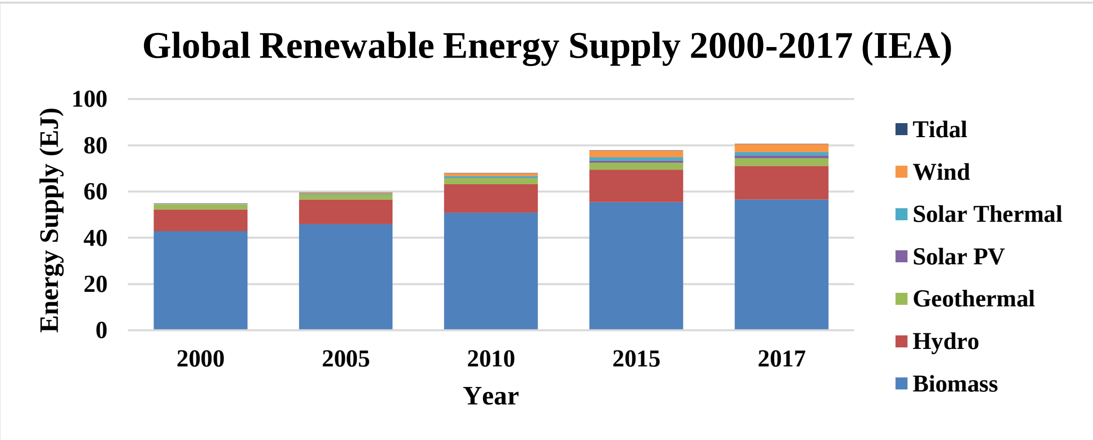

Figure 2.2 Global Renewable Energy Supply 2000-2017 (IEA)

The usage of biomass as an energy source can be categorized into two types: i) Traditional biomass and ii) Modern biomass. Traditional use refers to the direct burning of biomass, either for heating or cooking purposes. The usage of traditional biomass is predominant in developing countries of the world. Most of them being in Asian and African continents. While the modern biomass refers to the usage of biofuels made through up-gradation of biomass. The use of modern biomass is more common in developing countries of Northern America and Europe. Figure 2.3 represents a continent-wide comparison of bioenergy and total renewable energy supply, for the year 2017.

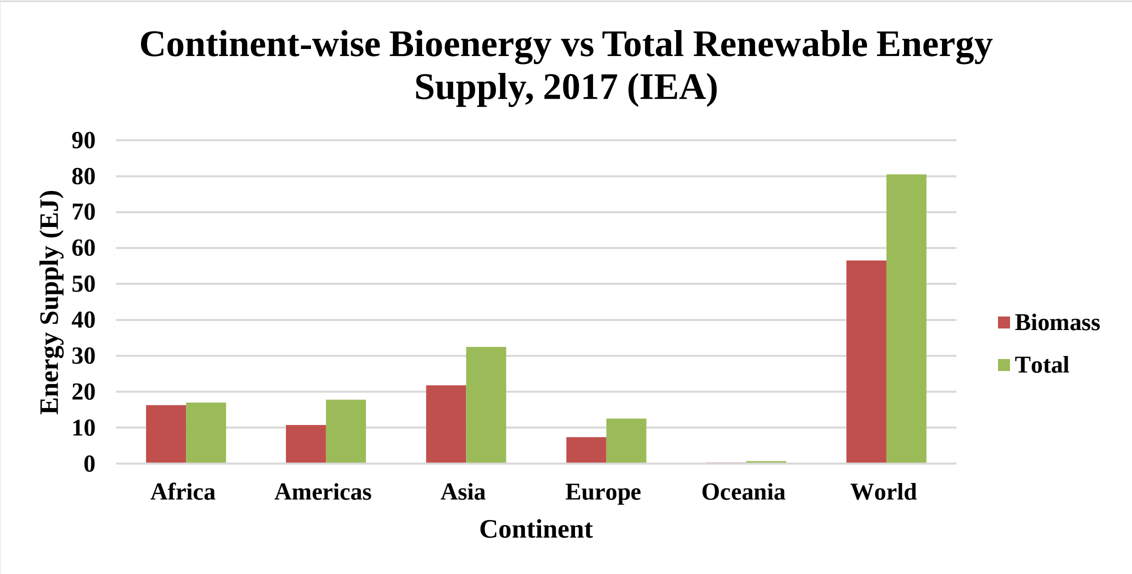

Figure 2.3 Continent-wise Bioenergy vs Total Renewable Energy Supply, 2017 (IEA)

2.3 Biomass and Bioenergy market studies of Pakistan

Bioenergy is one of the major sources of energy in Pakistan. both at domestic and industrial level bioenergy contributes a major source in the energy mix of Pakistan. according to IEA's estimates, Pakistan's one-third total primary energy supply comes from biofuels, which is 33736 KTOE (Kilo-tones oil equivalent) of bioenergy. Most of this usage is realized in the rural areas, where biomass is burned for heating and cooking purposes. According to Salman Naqvi et al [13], more than 62% of the rural population relied primarily on biomass for energy purposes. Whereas in the industrial side, biomass is burned to get process heat, mostly in small and medium-sized enterprises (SMEs). Along with SMEs most of the brick kilns across the country rely primarily on agricultural residue for energy purposes [14].

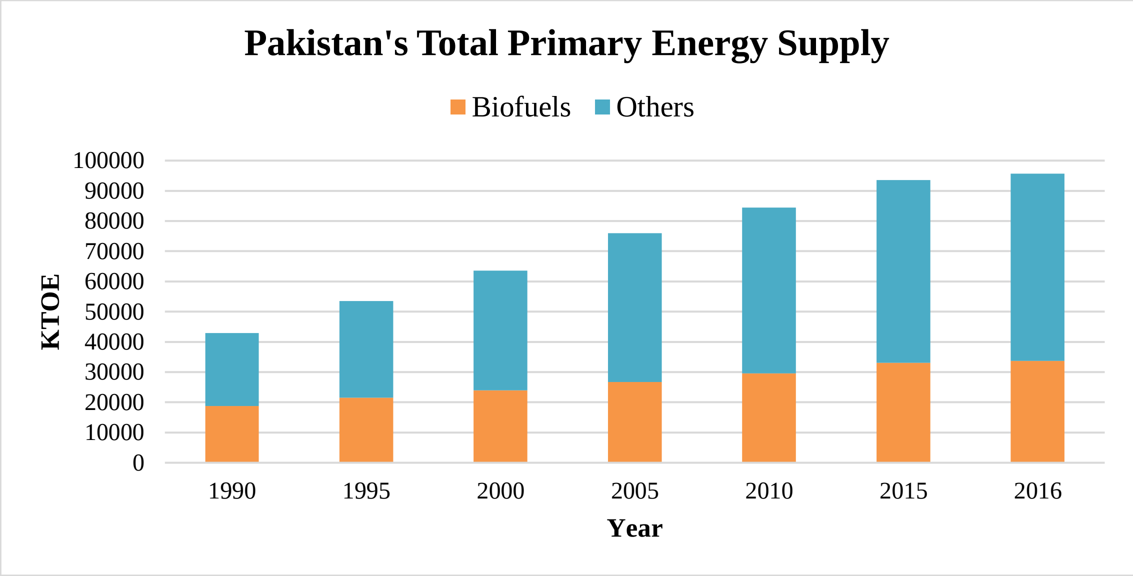

Figure 2.4 Pakistan's Total Primary Energy Supply (Source: IEA)

The first study of the bioenergy market of Pakistan was done by Umar Mirza et al. in 2008. According to the study, 67% of Pakistanis lived in rural areas, the majority of whom used traditional biomass for energy purposes. The traditional biomass being used include wood, agricultural residue, and animal dung. This study further recapitulated the bioenergy dissemination initiative took by the government of Pakistan. moreover, the study estimated the potential for biogas and energy generation from sugarcane bagasse and municipal solid waste [10].

According to the study did by M.J. Zuberi et al. [15] in 2013, the share of biomass/bioenergy in electricity generation stood at zero. The same study estimated a 3000 MW of electric power potential in the sugar industry, through the utilization of the sugarcane bagasse. While the total energy generation from livestock manure, crop residue, and municipal waste could meet 42% of electric power generation in the country for the year 2013.

In 2015, Muhamad Jibran et al. [16] published a research study estimating the energy potential of biomass in Pakistan, for the purpose of power generation and transportation. The primary biomass feedstock analyzed in this study was animal manure, solid waste, and sugarcane bagasse. The study estimated a total of 29.7 million m^3 of biogas generation from the given three sources. Which according to the same study was enough to cover 24% of the fuel required for power generation, at the time of publication. Whereas, estimations for usage in transportation was relatively dismal.

The study further suggested the prospects of introducing biomethane as a compliment to compressed natural gas (CNG).

Another study titled "Biogas potential for electric power generation in Pakistan: A survey" estimated the power generation from biogas at 35.625 million KWh of per day. Which would eventually generate an income in terms of energy-saving at 37.925 million rupees per month [17].

The major study taken in the field of biomass production and its potential in Pakistan is the study of 2016, titled 'Biomass atlas of Pakistan'. The study was published by the World Bank in cooperation with the Alternative energy development board (AEDB) of Pakistan. The study was a result of primary surveys for biomass production in the agriculture sector of Pakistan, and validation through GIS (Geographic information system) mapping [18]. The findings are: i) 25.3 million metric tons per year theoretical generation potential of crop processing residues, an equivalent of 222,620 TJ of energy generation per year (61,838 GWh_{th}/year), ii) a theoretical potential of crop harvesting residues at 114 million metric tons per year with an equivalent energy potential of 1,616,362 TJ/year (448,990 GWh_{th}/year), iii) new high-pressure cogeneration plants at 84 sugar mills across the country have a combined power capacity of 1,844 MW based on a total of 17.1 million metric tons of bagasse generated each year, iv) municipal solid waste (MSW) amounting to 27,000 metric tons per day (generated at 12 surveyed landfills), can provide around 360 MW of gross power capacity based on the anaerobic digester-based power generating technology.

Furthermore, the study calculated 'site suitability indicator' and generated maps for greenfield power plants utilizing crop residue as a fuel. Where a high site suitability value indicates a good location to build a power plant. For the calculation of site suitability factor, the following factors were considered: feedstock sourcing area size, road network density, and the distance to a nearby grid-station. Figure 2.5 shows the site suitability indicator, for a 15 MW power plant using inclined-grate combustion steam boiler and steam turbine, using a heat map.

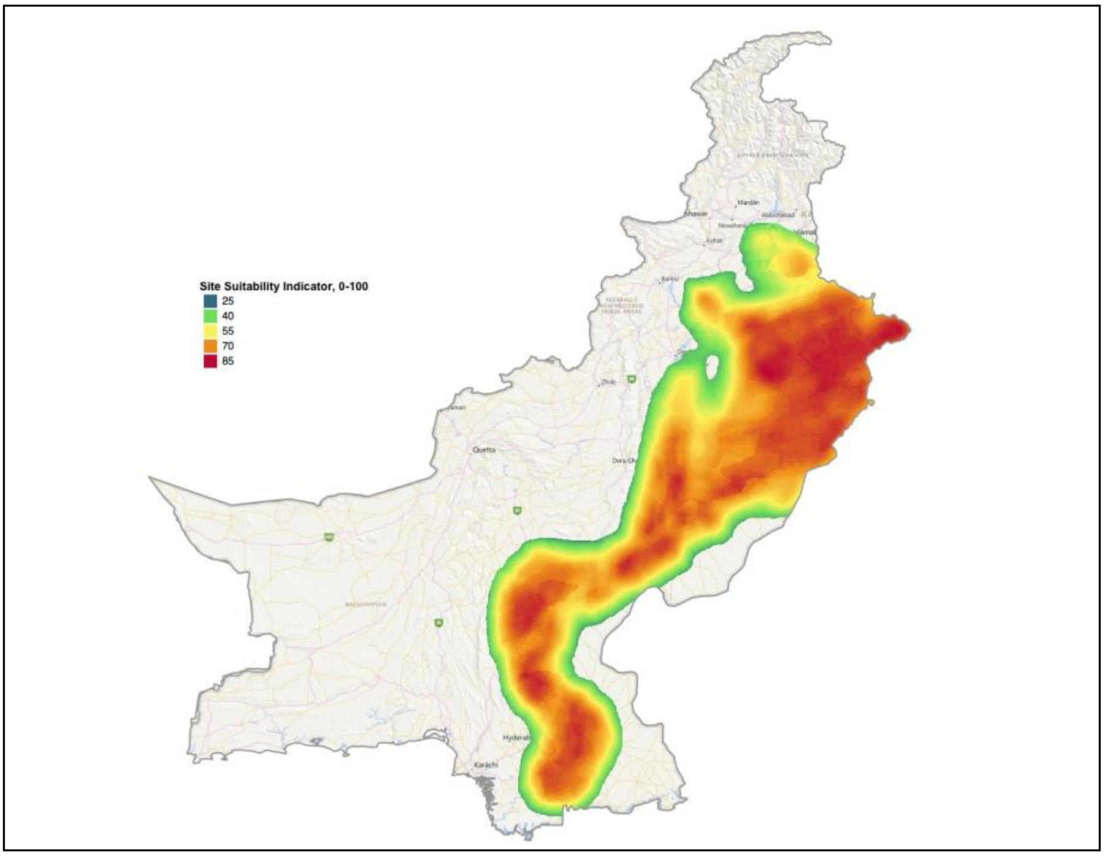

Figure 2.5 Site suitability indicator map for thermal power plants (Source: [18])

A recent study by Salman Naqvi et al. [13] studied the bioenergy technologies and their application in the case of Pakistan. the study further discussed the strategies for the development of biomass as a source of energy and its potential impacts on different sectors.

Most recent among the studies in this field include one by M.T. Khan et. al. [19] and Muhammad Yaseen et. al. [20]. M.T Khan studied the prospects of biofuels and bioenergy generation from sugarcane in Pakistan. The study concluded that ethanol production from sugarcane remains underexploited and it can help Pakistan in long term energy security. Similarly, the study was done by M.T. Khan et. al further emphasized utilizing biomass to reduce the energy shortage in the country. Furthermore, prospects of producing biofuels like pyrolysis vapors, char, syn gas, or bio-oil which can further produce methane, methanol, dimethyl ether and hydrogen is discussed in the study. Authors recommended to utilize the biofuels in heat, or electricity generation at small and medium scale.

2.4 History of Energy Policies in Pakistan with respect to bioenergy

To understand the policy situation a comprehensive review of energy policies is done in the following section. The review entails policies starting from Power policy 1994 to the upcoming Alternative and renewable energy policy. The results of the comprehensive review of energy policies of Pakistan is divided into two parts. One before the renewable energy policy of 2006 and the second section detailing post-2006 policies.

2.4.1 Pre-2006 energy policies and their relevance to bioenergy

2.4.1.1 Power Policy, 1994

The power policy of 1994 was promulgated by the then ruling party, the Pakistan people's party. This was a time of severe power shortages and policy was meant to address this issue [21]. The policy promulgated under the name 'Policy framework and package of incentives for private sector power generation projects in Pakistan'.

This policy provided the option to the power producer to choose between the fuel types and technologies. The policy doesn't mention bioenergy throughout the length of the document. Though there is a clause that refers to non-conventional sources of energy. "*Investors may also propose projects based on hydro, or other renewable and/or non-conventional sources of energy such as solar, wind, geothermal, etc.*"

The policy failed miserably to attract interest in any of the non-conventional energy generation, let alone bioenergy. As reported by Mirjat et al. the explanation for lack of investor interest included: lack of lucrative opportunities in bioenergy compared to other thermal powerplants [21]. Secondly, the policy didn't make any provisions for bioenergy or any other renewable energy to be added to the generation capacity for power producers.

2.4.1.2 Power Policy, 1998

The response to power policy in attracting investment in the energy sector was overwhelming. Therefore, the incumbent government promulgated the power policy of 1998. The primary intention being to create a competitive power generation market in the country [21]. Renewable energy was made a part of the policy. While the conventional power projects were required bid for solicited biddings, whereas power generation from renewable energy sources was exempted from such biddings. The policy further mentioned '*Thermal projects based on fuels other than indigenous coal*'. For interested parties to invest in such projects, they were required to provide a request for proposal (RFP). The policy further stated that the arrangements for such fuels were the responsibility of the bidder.

The final section of the policy refers to small powerplants (including cogeneration units) of capacity less than 20 MW, based on renewable sources. For the given powerplants, an exemption was made for solicited proposals and competitive bidding. Tariffs were to be set as average levelized-tariff, which is basically the average of the last twelve months. These plants were restricted to keep capacity increase within 5% per annum so that to ensure a competitive solicitation determination of tariff.

A provision for powerplants intending to provide power to off-grid places was made in the policy. Such power producers were allowed deviations from the given policy. At the same time, NEPRA was to establish separate procedures for attracting private investment and setting tariffs for such powerplants.

2.4.1.3 Policy for Power generation, 2002

Pakistan saw a political regime change in 1999, with the takeover by a military dictator. The new government with its bold economic goals felt the need for a new and comprehensive energy policy. The result was the Policy for power generation 2002. This was the first time that there was an explicit mention of indigenous renewable energy exploitation. The second objective stated, "*To encourage and ensure exploitation of indigenous resources, which include renewable energy resources, human resources, the participation of local engineering and manufacturing capabilities*". Again, in the policy, it refers to the Government of Pakistan's aim to initiate feasibility studies in power generation from indigenous renewable resources.

Renewable energy projects were classified as Raw sites. Such projects were required to submit proposals to provincial governments in case capacity lower than 50 MW. Whereas for the plant with capacity of above 50 MW were to submit proposals to PPIB (Private power infrastructure board). The maximum time, from submission of proposals to the provision of a Letter of support (LOS), was 465 days, which didn't include the feasibility study period.

2.4.2 Post-2006 energy policies and their relevance to bioenergy

2.4.2.1 Renewable Energy Policy, 2006

The renewable energy policy of 2006 was the first of its kind. This was the first time when the Government of Pakistan developed a comprehensive policy for the development of renewable energy in Pakistan. But this policy failed in catering to the needs of stakeholders concerned with bioenergy.

In the introduction, it is stated that "*Additional policy guidelines shall be issued in the future concerning biomass conversion and other RE technologies, as well as for non-power RE applications, as the sector grows, and technology advances take place*."

The scope of policy categorically states that RE technologies other than Small hydro, Solar (Photovoltaic + Thermal) and wind are not in the domain of this policy. The statement goes as follow "*Other RE power generation technologies—such as those based on municipal waste and landfill methane recovery, anaerobic or pyrolytic biomass gasification, cofiring or cogeneration utilizing agricultural crop residues, biofuels, wave, tidal, geothermal energy, and fuel cells—are also relevant to current and future renewable energy use in Pakistan. However, these are not dealt with within this document.*"

2.4.2.2 PPIB, National policy for power co-generation by the sugar industry, 2008

This policy came two years after the first Renewable energy policy was first promulgated. But this policy depends on fiscal and legal regimes of Power Policy of 2002. Tariff determination is done through the procedure discussed in the Power policy of 2002 by NEPRA. Co-generation policy allowed sugar mill owners to have power-producing plants that can be run as either in Captive or IPP mode as well. Another provision also allowed the sugar industry to use bagasse as fuel during crushing season and coal (local or imported) during the off-season period. Here crushing season refers to sugarcane crushing/harvesting season i.e. November to February and off-season as March to October months.

Another important provision from power policy 2002 was the imposition of fixed customs duty at 5%, on machinery imported for such projects. Another clause mentions "*indigenization to be maximized in accordance with government policy"* but doesn't mention how this will be achieved.

2.4.2.3 Framework for Bagasse Power Co-Generation, 2013

Framework for Power co-generation was formally approved as an addition to the RE policy of 2006 by ECC (Economic Coordination Committee) of the Cabinet in 2013. As RE policy was silent regarding Bioenergy projects, this time Bioenergy projects utilizing Bagasse, biomass, and waste were added to the scope of the RE policy 2006. This meant that all the fiscal, institutional and regulatory regimes of the 2006 policy will be applicable to Bioenergy projects, whereas power policy of 2002 was the basic regulatory model for 2008's Cogeneration policy. ECC also extended the policy regime for RE policy 2006 by another five years [22].

The addition of biomass to the RE policy of 2006 was a positive step took by ECC. The inclusion led the bioenergy producers, sugar-mill owners currently, to access the incentives provided to other RE technologies. Which included Carbon credits, Energy banking and guaranteed power purchase by central power purchasing authority (CPPA).

Other major features of the policy included: Facilitation of PPIB in setting up of the co-generation power plants, using high-pressure boilers i.e. a minimum of 60 bars. Co-generation plants will be able to access the financial incentives of Power policy 2002. All eligible companies were exempted from the prequalification process. They were to be issued a letter of support by PPIB after tariff has been determined by NEPRA. A major change was from earlier polices was that power producer was bound to dispatch hourly declared available capacity during the crushing season.

2.4.2.4 Alternative and Renewable energy (ARE) policy 2019

ARE policy though not promulgated officially, is in the review phase. The draft of the policy has been shared among stakeholders in academia and policy think tanks. The draft of the ARE policy shows some dramatic changes from the earlier policies. The new policy has broadened its scope, the flexibility of implementation, introduced competitive procurement of energy, emphasis on off-grid solutions and rural energy services. The policy sets a bold target of achieving 20 per cent of the energy mix from renewables by 2025 and 30 per cent by 2030. Keeping the timeframe in focus, achieving 20 per cent energy from renewables by 2025 seems impractical.

This time bioenergy has been given the same focus as that of wind and solar. The scope now includes energy from biomass, this time extended from bagasse to other agricultural residues and wastes, Biogas and energy from waste which includes municipal and industrial waste, sewage and refused derived fuels.

ARE policy is continuing most of the incentives provided under the RE policy of 2006. Incentives like tax exemptions and custom duty exemptions remain there. Regulatory tools like net metering, energy wheeling, carbon credits, and upfront tariffs are also part of the policy. While, Upfront tariffs are up to NEPRA to decide, depending on the nature of the project. Another addition to this policy is International Competitive Bidding (ICB). ICB will consider the energy source that provides the least cost. This may put bioenergy projects at disadvantage compared to conventional fuels, because of existing infrastructure and economies of scale.

Though the objectives include rural energy services and to encourage the private sector, Fiscal incentives remain out of the scope of the new policy. There are no provisions made for public loans, guarantees and investment in bioenergy or other renewable energy projects.

2.5 Review of Bioenergy Initiatives

The literature review provides no initiatives took until the advent of the 1970s [10]. Due to rising oil prices of that decade, the government of Pakistan started a campaign for indigenous energy solutions. The following are some of the initiatives taken by the public, private and non-governmental organizations for the development of bioenergy in Pakistan.

2.5.1 Public sector bioenergy initiatives

2.5.1.1 Biogas technology dissemination program (1974)

Directorate general new and renewable energy resources (DGNRER) worked under the umbrella of the Ministry of Petroleum and Natural Resources. DGNRER started a countrywide biogas technology dissemination program in 1974, which came to an end in 1987. During this period a total of 4137 biogas plants were installed across Pakistan.

The biogas plants had a capacity of 3000 to 5000 ft^3/day [10]. The project was completed in three phases, as described below.

- Phase 1: First 100 demonstration plants installed, funded by DGNRER.
- Phase 2: Further plants to be installed on a cost-sharing basis.
- Phase 3: Remaining plants to be financed by the consumer.

According to Umar K et.al [10], the program failed due to the following reasons, Lack of technical expertise for operation and maintenance of the biogas plants, unavailability of government's financial support, and lack of awareness among adopting communities. While K.M. Mittal [23] reported that, in 1980 DGNRER proposed another 15000 biogas plants to be installed, which would cater to 2000 villages under this project. In 1993 DGNRER was dissolved and a project like "Dissemination of Biogas Technology" was handed over to PCAT.

2.5.1.2 Propagation of biogas technology – Phase I (1976)

Pakistan council of appropriate technology (PCAT) is the parent institution of today's PCRET (Pakistan council of renewable technologies). PCAT undertook an initiative named 'Propagation of Biogas Technology' in 1976. The project intended to assess the feasibility of Chinese fixed dome biogas plant in Pakistan. Under this project 21 Chinese fixed dome biogas plants were installed. These plants couldn't prove to be effective due to defects of design. The problem with these plants was the formation of cracks in the domes of the plants. Biogas created in the plant escaped through these cracks. PCAT couldn't prepare manpower possessing skills in operation and maintenance of such plants. Eventually, the program was abandoned and PCAT moved to implement Indian Design [24].

2.5.1.3 Propagation of biogas technology – Phase II (1979)

Due to the failure of Chinese designs, PCAT adopted Moveable gasholder design. This design had Indian origin, but it was reengineered and modified to be manufactured easily in Pakistan. The first 10 demonstrations plants were set up in areas of Azad Kashmir. These plants were able to withstand the atmospheric conditions of Pakistan. No major issue was reported of these plants. According to PCRET's website, one of the biogas plants is still functional [25].

After the success of the demonstration plants, another 100 biogas plants were installed across Pakistan under the Public sector development program in 1980 [24]. Owing to the success of PCAT's experiment with 10 biogas plants in Azad Kashmir and 100 biogas plants under PSDP, provincial governments financed the implementation of another 350 biogas plants [25].

2.5.1.4 Bioenergy initiatives by PCRET (2002-2012)

In 2002 PCRET got a grant under a project named PC-1 for installation of biogas plants (1200 in total). Finance of Rupees 22.02 Million was provisioned for this project, it is not clear which organization was a source of funding for this project. According to PCRET's website [25], PCRET installed a total of 1600 biogas plants by the end of the project i.e. June 2006 [26].

Under another project financed by the Public sector development program, PCRET installed another 2500 biogas plants [10][25]. These plants were installed in different rural areas of Pakistan. The project lasted for two years. The project was implemented through a fifty per cent cost-sharing basis among beneficiary and PCRET.

A total of 2513 biogas plants were installed in the period starting from 2007 to 2012. PCRET has set an ambitious target of 50000 biogas plants to be installed by 2020, with a cumulative capacity of 0.3 million m^3 of biogas/day [17][27]. While PCRET's work in the past has been praiseworthy, but for the given target there has not been any plan publicized. At the time of writing this paper, June 2019, there is silence from both independent reporters and from PCRET about the extent to which the target has been achieved.

2.5.1.5 Adaptation of Biogas Technology to Mitigate Energy Crises (2013)

The agriculture department of Punjab is also working towards the dissemination of biogas technology among rural areas of Punjab. Under the name "Adaptation of Biogas Technology to Mitigate Energy Crises" 750 biogas plants of 15 m^3 were installed across Punjab. These plants were meant to provide biogas for household energy requirements of cooking and heating. Another 1200 floating-drum type biogas plants were provided to small and medium-scale farmers, to run tube-wells [24]. The agriculture department with assistance from energy ministry has set a target of setting up biogas powered tube-wells. Provisions were made for providing subsidies for biogas powered tube-wells up to a Hundred thousand rupees for small landholders [28].

2.5.2 Bioenergy initiatives took by the private sector

2.5.2.1 RSPN bioenergy initiatives

In 2009 RSPN installed a total of 70 biogas plants across Pakistan on a subsidized cost [29]**.** Each beneficiary received a sum of 7500 rupees as a subsidy on the biogas plant. Another program was initiated by RSPN in 2014, named Pakistan domestic biogas program (PDBP). Under PDBP a total of 5360 biogas plants were installed. The plants were installed across 12 central districts of Punjab province. Sargodha district had the highest number of plants installed under this project, counting to 1177, followed by Jhang with 991 plants [30]. Biogas plants installed under PDBP were of Fixed dome type, a Nepalese design.

2.5.2.2 FIDA bioenergy initiatives

Foundation for Integrated Development Action (FIDA) is an NGO working in Dera Ismail Khan (DI-Khan) and neighbouring areas of Khyber-Pakhtun-Khuwa province. In 2007 FIDA successfully implemented the installation of four different size pilot plants in DI-Khan [27]**.** The project was implemented with the collaboration of RSPN. According to FIDA beneficiaries of the project included twenty-two households or 162 people.

Another seven biogas plants were installed in the DI-Khan area under the sponsorship of the Australian Agency for international development in 2009. Beneficiaries included fifteen households. While in 2012 FIDA completed the commissioning of 175 biogas plants in DI-Khan. The project was named ‘Alternative Rural Energy Through Community-Led Biogas’, funding source was the United States Agency for international development (USAID). According to FIDA’s website, a total of 657 biogas plants were installed through different programs, with the collaboration of different international NGOs from 2012 to 2015 [31].

2.5.2.3 PDDC bioenergy initiatives

Pakistan Dairy development centre (PDDC) is a private institute working for the development of the dairy sector in Pakistan. PDDC provides training for capacity building among dairy workers and stakeholders. Under the project named Horizon 3, PDDC has installed 450 biogas plants in rural areas of Pakistan. Another 106 plants were installed by PDDC following completion of the first 450 plants in July 2009. The cost of procurement and installation is subsidized, with 50% paid by PDDC [32].

Summary

This chapter reviewed literature firstly for the bioenergy market and trends globally. Globally bioenergy is a major contributor to the final energy consumption, same being the case for Pakistan as well. Which is partly due to the lack of access to modern energy fuels which are primarily based on fossil fuels. There remains a huge untapped potential of bioenergy in Pakistan, which through proper planning and execution can help the country in energy security, increasing economic activity, employment generation and reduced reliance on foreign energy imports. Secondly, an overview of the bioenergy market of Pakistan was presented through a chronological presentation of previous studies. The literature review summarizes studies undertaken by different researchers to understand the energy market of Pakistan. The first study being done by Umer Mirza and onwards by likes of M.J. Zuberi, Muhamad Jibran and Salman Naqvi. Every author presented an estimation of bioenergy resources in Pakistan. Whereas, the first on ground study was carried out World Bank and Alternative energy development board in 2016, titled as ‘Biomass atlas of Pakistan’. The study was a result of primary surveys for biomass production in the agriculture sector of Pakistan, and validation through GIS (Geographic information system) mapping. This study calculated the total agricultural residue generated in Pakistan annually and the feasibility of bioenergy generation from this residue. Furthermore, the literature review includes a comprehensive review of energy policies is done in the following section. The review entails policies starting from Power policy 1994 to the upcoming Alternative and renewable energy policy. The results of the comprehensive review of energy policies of Pakistan is divided into two parts. One before the renewable energy policy of 2006 and the second section detailing post-2006 policies. The final part of the literature review summarizes the bioenergy initiatives taken by public and private sectors in Pakistan.

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Chapter 3 Methodology

The main objective of this research work was to study the bioenergy market of Pakistan. For a better understanding of the market, the study first analyzed and evaluated the policy situation in Pakistan first. The first section of this study deals with the evolution of energy policies by analyzing, evaluating and comparing them for their merits and demerits. The second section carries out a comprehensive strength, weaknesses, opportunities, and threats (SWOT) analysis of the bioenergy sector of Pakistan.

3.1 Analysis and evaluation of energy policies of Pakistan

The purpose of analysis and evaluation of policies is to do a detailed examination of the policies and then evaluate them for their impact on the development of bioenergy. The analysis focusses more on the qualitative aspects of policy whereas evaluation quantifies the effectiveness of the policy.

Policy analysis has been in the limelight of researchers, but no text provides a consistent framework for the analysis of energy policy, especially for renewable and bioenergy context [1]. While authors have been proposing methods for better energy planning and policymaking [2], [3], [4], but most fail in proposing a comprehensive framework for the analysis of the present policies. Therefore, this study intends to propose comprehensive frameworks both for analysis and evaluation of policy effectiveness.

3.1.1 Framework for analysis and comparison of policies

The purpose of analysis of policies is to do a detailed examination of the policies by disassembling them into its constituent elements and thereby interpret it in terms of those constituent elements. Studies done prior to this have studied policies for their effectiveness in terms of renewable energy development, specifically in the United States and European Union [5], [6], [7], [8]. Each study takes its own method to analyze the policy or rather deal with the post-policy results. None of the studies provides a framework to analyze a given policy. Therefore, this study aims to propose a framework for policy analysis that can be replicated and reused in future energy policy studies.

The first step in this study is to prepare a framework to analyze the policies is to look for specific policy-options in the given policy, that have proven to create demand for bioenergy technologies earlier in the energy market of other countries. A comprehensive review of different working papers was done to identify the parameters to study the energy policy options. This resulted in the identification of 43 energy policy options to analyze energy policy. The list of the complete policy options identified is tabulated in Table A.1.

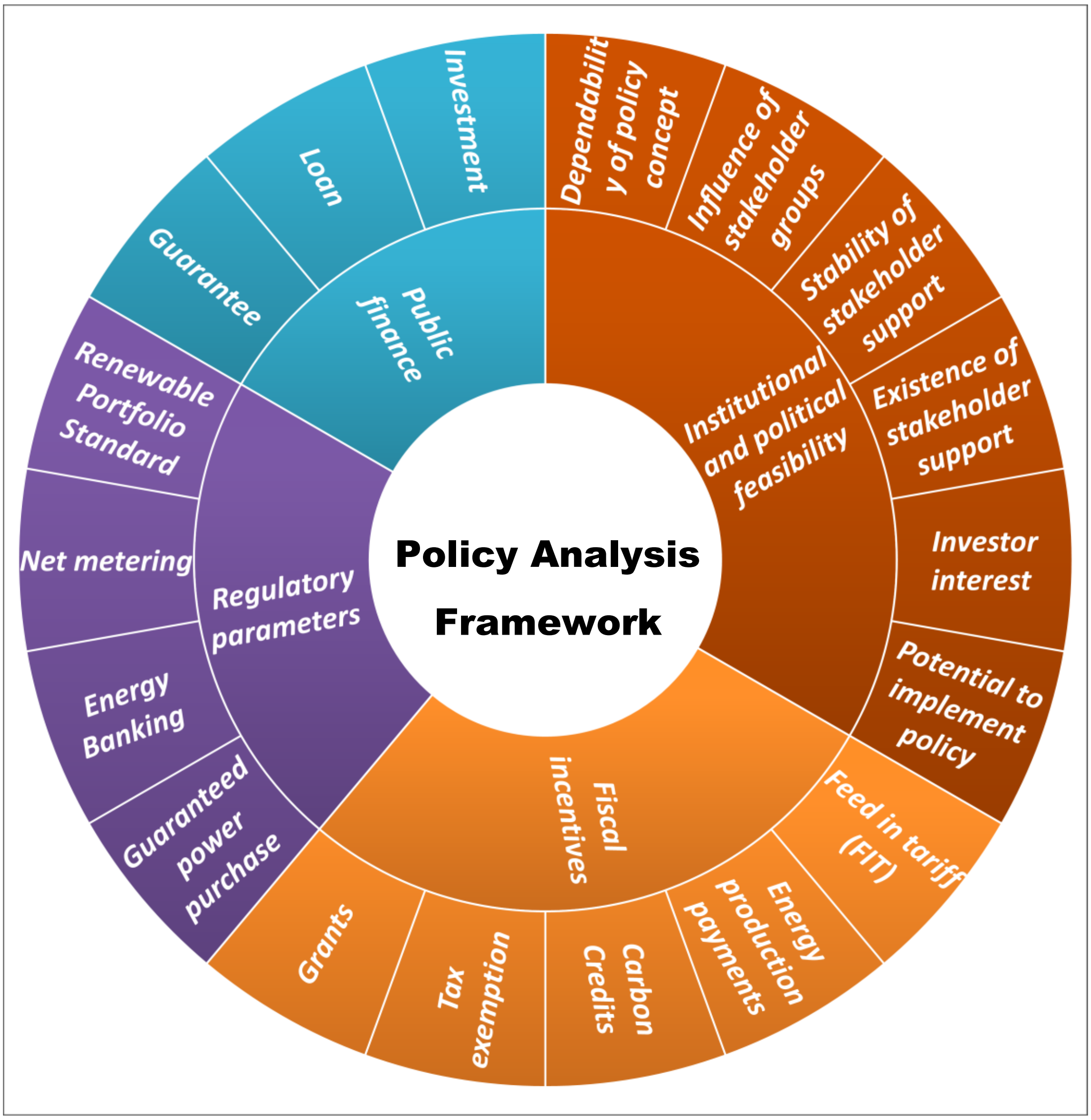

Figure 3.1 Policy analysis framework

The second step in preparing to devise the framework was to finalize the parameters to be used. After long deliberations into the parameters identified, a comprehensive criterion was formed for the final selection of parameters for the framework. The criteria investigated the applicability of parameters identified, for the case of Pakistan or a similar developing country. The final selection of indicator was done based on the following criteria:

1. Drivers of deployment: Policy options that help in driving the deployment of bioenergy technologies.
2. Balance: indicators within each category exhibit coverage of different issues of renewable energy policy.
3. Relevance: indicators are chosen or developed to provide insight into country situations in the context of the policy goals.
4. Dependability: Policy options that have been proved effective for the deployment of bioenergy (renewable energy) prior to this study.
5. Distinctiveness: each indicator focuses on a different aspect of the issue being explored and avoids overlaps or redundancy with other indicators.

After applying the criteria defined above, a total of 16 qualitative indicators were finalized to analyze and later compare the policies. The indicators have been chosen after consideration for their applicability to suit the situation of Pakistan or a likewise developing country. This study compared the policies for the number of indicators fulfilled or discussed in the policy. The extent to which such a variable is fulfilled is not considered, keeping the fact in mind that these indicators are qualitative in nature. The indicators are grouped into five major categories, i.e. fiscal incentives, public finance, regulatory parameters, institutional feasibility, and political viability. The indicators are enlisted in Figure 3.1 and the nature of the indicators is explained in the following section.

3.1.1.1 Fiscal Incentives

Fiscal incentives are incentives relating to finance, that have been offered earlier by different countries around the globe for maximizing the deployment of Renewable energy. Employing such incentives can reduce upfront costs and investments related to bioenergy technology [9], [10].

Grants are the monetary assistance provided by the government for the implementation of new projects. Grants are one-time payments that do not have to be repaid. Grants are usually provided in the form of refunds after the investment has been made by the investor.

Tax reduction/ exemption incentives directly provide the power producer with a reduction in taxes, which may include sales, value-added, energy or carbon tax. Such incentives are also applied to the purchase (or production) of bioenergy or other renewable energy technologies.

Carbon Credits are credits given to the power producer, mostly under the Clean Development Mechanism (CDM). Which are based on reductions in carbon (Carbon dioxide) emissions as compared to a traditional fuel-based power generation like power production using oil or coal-based.

Energy production payments are direct payments, paid to the energy produced by the government for each unit of renewable energy produced. Such payments may vary in size and the extent to which they are offered. Which may extend up to the first few years of energy production.

Feed-in tariff (FIT) is one of the most popularly used fiscal incentives provided to energy producers in developed as well as developing countries. FIT is a fixed amount paid to the supplier (varying by technology) per unit energy delivered in the given year. FIT can be related to Energy production payment.

3.1.1.2 Public Finance

The indicators under the public finance category show how interested the government or state institutions in providing finance to the bioenergy, or other renewable, projects. The provision of public finance is essential for the development of bioenergy and other renewable energy technologies [9], [11]. The provision of public finance can trigger private investment into renewable energy technologies as well. The following are some of the types of public finance instruments.

Investment is the direct participation of public finance institutes in the bioenergy projects. Where public institutions provide finance for a share of equity in the given project/company. Such investments can be made through a venture fund model or through technology development funds.

Loan is another type of public finance. Where eligible or economically viable bioenergy projects are given loans for the execution of the project. Loans may not be limited to those provided by public financial institutions. They can be extended to private financial institutions as well. This may differ from general loans in terms of low-interest rates.

Guarantee doesn't involve direct provision of finance, it is just a role to be fulfilled by public financial institutes. To provide a guarantee a public institute provides the role of guarantor for RE companies/projects, which are seeking loans from commercial banks or other financial institutes. Guarantees are provided to people or businesses with sound financial background or a sound business strategy.

3.1.1.3 Regulatory Parameters

Such parameters indicate how the government is regulating the power generation sector, either public or private, in order to increase the share of bioenergy or other renewable energy in power generation.

Renewable Portfolio Standard (RFS)/ Quota obligation/ Renewable mandate are terminologies used to describe the same concept. To make sure there is enough green energy being produced, renewable mandates are introduced. Such mandates require existing power producers to meet a minimum target to include bioenergy in the energy generation portfolio.

Net-metering (or net billing) is another important regulatory parameter. Net metering is introduced to encourage small and medium-scale energy generation projects. Under net-metering, anyone with surplus power (renewable in this case) is allowed a two-way flow of energy between the energy dispatch company and power producer (Captive).

Energy Banking is just like the traditional banking system, where energy is deposited and withdrawn accordingly. This regulatory tool allows a business or a person to invest in a renewable energy plant, elsewhere than his residence. Such an investor is privileged to access energy at his choice of location in the same amount as his power plant produces.

Guaranteed power purchase is the guarantee provided to power producers. Guaranteed power purchase agreements are made to prioritize and ensure a buildup of the renewable energy sector. This incentive guarantees the purchase of every unit of power produced by the RE producer.

3.1.1.4 Institutional and political feasibility

Potential to implement policy refers to the presence of institutions that makes provisions for registration and regulation of different RE projects.

Investor interest shows the interest of the investor to invest in the given technology and present political situation. Which can be easily assessed by the number of applications received and projects implemented.

Existence of stakeholder support shows, how a stakeholder is facilitated under different situations. That may include any sort of crisis or a political regime change.

Stability of stakeholder support reports on the existence of long-term support for stakeholders. This parameter is hired to seek whether the government targets are consistent over time with the incentives for stakeholders to adhere to the policy.

Influence of stakeholder groups is involved to assess policy's scope with respect to stakeholders' interests. This parameter gives an overview of stakeholder influence. Which includes ownership of key industries.

Dependability of policy concept means the presence of comparable policies elsewhere, and the success of such policies in countries with similar contexts.

3.1.2 Framework for evaluation of bioenergy policy effectiveness

While, the analysis of policies focused on the content of policies for their intent to create an optimal situation for the development of bioenergy, evaluation of policies focuses more on their impact and the results of such policy options. The primary focus of the evaluation is to gauge the effectiveness of a policy. As described by Mitchell et. al [12], the effectiveness is the extent to which intended objectives are met, for example, the actual increase in the amount of renewable electricity generated or share of renewables in the total energy mix, within a specified time period.

The framework for the evaluation process assesses the policies on a broad spectrum of aspects. Which includes energy security, environmental impact, economic impact and equity impact of the policy. For ease of use, the framework is named as EE-S (Environment, Economy, and Security) framework for bioenergy policy evaluation. Though this study focusses on bioenergy policies, the framework is equally applicable to other renewable energy technologies or the combination of any two or more.

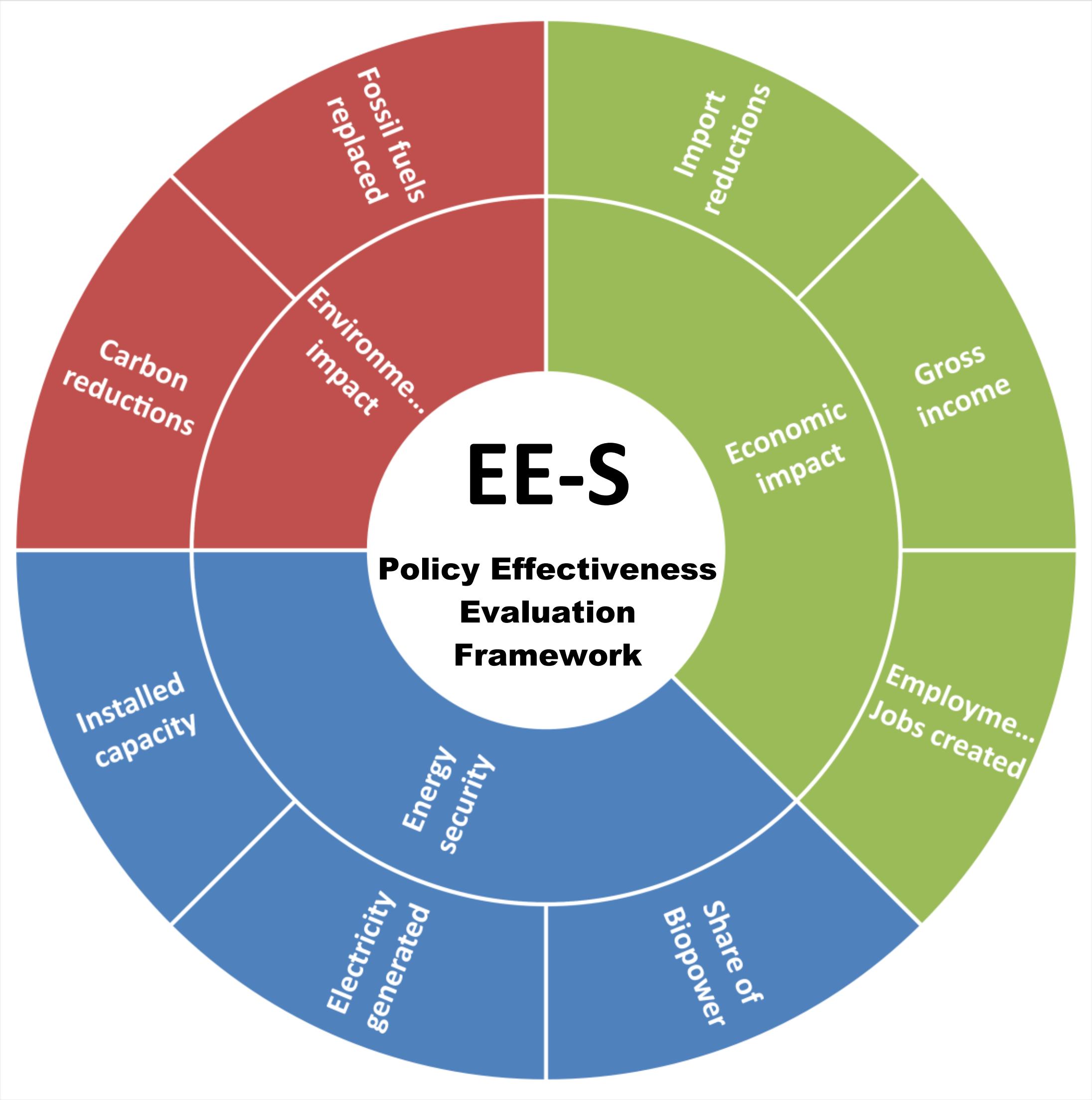

Figure 3.2 EE-S Policy Effectiveness Evaluation Framework

The selection criteria of policy evaluation indicators are as follow:

1. Balance: indicators within each category (and indicators across the Index) exhibit coverage of different issues of renewable energy policy.
2. Robustness: indicator scores are computed from data made available by reputable sources with the most current information available with sufficient coverage.
3. Relevance: indicators are chosen or developed to provide insight into country situations in the context of the policy goals.
4. Contextual sensitivity: for wider applications and comparing different country situations, where appropriate values used for indicators are normalized one, i.e. carbon emissions per capita, energy intensity per capita.

5. Comparability: data to calculate indicator scores are derived from as unique and comprehensive sources as possible, focusing on a single source per indicator as far as practicable, to ensure comparability.
6. Distinctiveness: each indicator focuses on a different aspect of the issue being explored and avoids overlaps or redundancy with other indicators.

Employing the above criteria, a total of 12 quantitative indicators were chosen across the four categories identified for evaluation purposes. The following sub-section sheds light on the chosen indicators that are employed to assess the effectiveness of the policies.

3.1.2.1 Energy security through bioenergy

The following four parameters were identified, to evaluate the policy in terms of energy security through the deployment of bioenergy. Energy security, which in words of J. G. Speight is the timely investments in long-term to supply energy in line with economic developments and sustainable environmental needs" [13].

Installed capacity is the total installed bioenergy based electric power generation capacity in megawatts (MW), in the final year of the life-span of the given policy.

Electricity generated is the total electric energy generated, in gigawatt-hours (GWh) in the given year from bioenergy powerplants and other biomass to bioenergy methods.

Share of Biopower is the per cent share of electric energy generation from biomass-based powerplants with respect to total electric energy generation in the country in the given year.

3.1.2.2 Environmental impact of bioenergy generation

Though environmental impact assessment is done before a powerplant is commissioned. But the actual environmental impact may not be necessarily the same. The following two policy evaluation parameters have been employed to evaluate the environmental impacts of bioenergy generation. The nominal values used for both parameters are from the report by the U.S. Energy information agency (EIA) [14], [15].

Fossil fuels replaced is the number of fossil fuels being replaced, considering that the same amount of energy is produced using petroleum products in a thermal power plant. For this study, a nominal value of 511.9 kWh per Barrel of Petroleum is used to calculate fossil fuels replaced.

Carbon reduction is the amount of carbon (CO_2) emissions reduced as a result of using bioenergy sources. Though bioenergy projects emit carbon dioxide, a consideration is made that the same amount of carbon dioxide is used by the plants in the production of biomass. The carbon emission value used is one pound of carbon dioxide per Kilowatt-hour of energy generated (1l bs/KWh or 0.457 kg/KWh).

3.1.2.3 Economic impact of bioenergy generation

Economic justification is one of the criteria for a policy to be justified. The next three parameters deal with the economic impact of energy generation from biomass, over the lifespan of the given policy.

Employment/ Jobs Created is the number of jobs created in the bioenergy industry. This includes personnel for Supply chain, Operations, and maintenance. This study employed the findings of Dalton and Lewis [16] i.e. 5.8 jobs (3.5 Direct jobs and 2.3 Operation and maintenance jobs) per MW of Bioenergy installation.

Gross Income is the amount of capital generated by the bioenergy companies by selling electricity to the national grid. The study doesn't consider savings made due to captive power generation because of the limitation of data availability. Gross income has been calculated using the tariff determined by NEPRA for the base year i.e. 2017.

Import reductions are the reduction in import bill as a result of replacing fossil fuels with bioenergy resources for power generation. Import reductions are calculated using the number of petroleum barrels replaced, calculated in economic impact, and the average price of petroleum barrel for that year.

3.2 SWOT analysis of bioenergy generation in Pakistan

Internal	**Strengths** The characteristics of the business or project that give it an advantage over others	**Weaknesses** The characteristics that places the business or project at a disadvantage relative to others
External	**Opportunities** The elements that the project could exploit to its advantage	**Threats** The elements in the environment that could cause trouble for the business or project

Figure 3.1 Breakdown of SWOT Analysis scheme

The methodology used to analyze the bioenergy generation in Pakistan is Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis. The SWOT analysis evaluates the given situation, organization or proposal based on the factors affecting it either internally or externally. Internal factors are classified into two categories, strengths and weaknesses. Whereas, external factors are categorized into two categories, opportunities, and threats [18]. Figure 3.3 gives entails the details of each of the SWOT categories. Strengths and opportunities include factors that are favourable to the topic, while, weaknesses and threats include factors that can adversely affect the feasibility of the given topic.

The SWOT analysis was principally developed for businesses intending to analyze their markets, but afterwards, it has been used extensively used for research purposes [19]. SWOT analysis has also been used by researchers, planners, and policymakers for energy planning. In this regard, Xunpeng Shi did a study using SWOT analysis to assess the future of energy mix in ASEAN (Association of Southeast Asian Nations) region [20]. The usage of SWOT for different purposes in the energy sector is summarized in Table 3.1.

Table 3.1 Prior use of SWOT analysis

Year	Author	Title	Objectives
1996	B. Naidu [21]	Indian scenario of renewable energy for sustainable development	To assess the renewable energy potential in India in the electricity sector, using SWOT analysis to further explore the possibilities of adopting renewable energy for sustainable development.
2007	J. Terrados et. al. [22]	Regional energy planning through SWOT analysis and strategic planning tools.: Impact on renewables development	Use SWOT analysis as an alternative to MCDA (multicriteria decision-making analysis), to diagnose current problems and to sketch future action lines for the exploitation of renewable energy resources, including solar and bioenergy.

2012	Y. bai [23]	SWOT analysis for the sustainable development of new energy industry in Hebei province	SWOT analysis for sustainable energy deployment in the industries of Hebei (Province of China).
2014	Wei Ming Chen et. al. [24]	RE in eastern Asia: RE policy review and comparative SWOT analysis for promoting renewable energy in Japan, South Korea, and Taiwan	Review of the development of renewable energy policies and roadmaps. SWOT analysis of the given countries, in proceeding the renewable energy policies and technologies.
2015	Xunpeng Shi [20]	The future of ASEAN energy mix: A SWOT analysis	Assessment of competing outlooks for energy mix in the ASEAN region, for the transition from fossil fuels to the green energy mix.
2017	Beyzanur Cayir Ervurala et. al. [25]	An ANP and fuzzy TOPSIS-based SWOT analysis for Turkey's energy planning	Propose a comprehensive and integrated methodology for the analysis of Turkey's energy sector using a combination of SWOT analysis and ANP (Analytic Network Process) process, and weighted fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution).
2020	Yasir Ahmed Solangi et. al. [26]	Evaluating the strategies for sustainable energy planning in Pakistan: An	Propose a methodology encompassing SWOT, AHP, and F-TOPSIS to evaluate energy planning strategies for sustainable energy planning.

integrated SWOT-
AHP and Fuzzy-
TOPSIS approach

The methodology used in this study to identify strengths, weaknesses, opportunities, and threats in the bioenergy market of Pakistan utilizes both bottom-up and top-down approaches. The bottom-up approach identified factors impacting bioenergy dissemination from ground level, through an extensive study of literature and comparing them with countries with a similar socio-economic situation. Whereas, in the top-down approach, the factors are identified, through the study of relevant policies, legislations and the statistics for bioenergy in the country.

In order to define the strengths, weaknesses, opportunities, and threats, the study posed the following questions:

1. Presence of the natural conditions for the development of bioenergy sources
2. Interest among investors and authorities in the development of bioenergy.
3. The current level of knowledge of bioenergy technologies among the populace.
4. Presence of skilled labour force to implement bioenergy technologies.
5. Public stance towards bioenergy, positive or negative.
6. Initial investment costs and operations and maintenance costs.
7. The profitability of new power plants and the rate of returns.
8. The economic impact of new bioenergy plants.
9. Social impact of new bioenergy plants.
10. Potential power plant sites and their feasibility to connect to the national grid.
11. Potential for power provision to Off-grid population.
12. Competition with traditional energy sources like coal and petroleum products.
13. Security of biomass supply chain.
14. The current state of research in bioenergy, nationally and globally.
15. Government grants, subsidies, and tax reductions or exemptions.
16. Policy instruments to encourage existing power producers to shift towards bioenergy i.e. renewable portfolio standards, green certificates, or carbon credits.
17. The coherence of energy, environmental and climate policy.
18. Ease of registration and facilitation for new power producers.
19. Presence of cooperation within state institutes and with private organizations.

20. Level of cooperation between federal and provincial governments and institutes.
21. Impact on the environment of bioenergy generation.
22. The extent to which environmental standards are followed, when commissioning a new plant.

Second step in carrying out SWOT analysis is to substantiate the results of SWOT analysis and to validate the objectivity of the analysis. A questionnaire was formed using the questions of SWOT analysis and shared with stakeholders in energy sector of Pakistan. the questionnaire used a Likert scale approach to scale responses. With 0 being low/negative and 10 being high/positive. In the end of survey, a comparison is made of opinion of the stakeholder in energy sector and authors own analysis of the given question.

Finally, a set of recommendations was proposed on how to utilize the untapped bioenergy potential optimally and move toward a sustainable bioenergy future. The recommendations are tailored to the identified strengths, weaknesses, opportunities and threats, such that to utilize the strengths, eliminate the weaknesses, exploit the opportunities and lessen the effect of the threats.

Summary

This chapter discussed in detail the methodology used in the research work to study the bioenergy market of Pakistan. The first step was to develop a framework for the analysis of policy and secondly for the evaluation of the given policy's effectiveness. The purpose of analysis and evaluation of policies is to do a detailed examination of the policies and then evaluate them for their impact on the development of bioenergy. The analysis focusses more on the qualitative aspects of policy whereas evaluation quantifies the effectiveness of the policy. The criteria for the selection of variables and parameters for analysis and evaluation are discussed in this chapter. A comprehensive review of different working papers was done to identify the parameters to study the energy policy options. This resulted in the identification of 43 energy policy options to analyze energy policy. Out of the 43 energy policy options identified, 18 were finalized to create the framework for policy analysis. The framework developed for the evaluation process assesses the policies on a broad spectrum of aspects. Which includes energy security, environmental impact, economic impact and equity impact of the policy. The framework proposed in this study is named as EE-S (Environment, Economy, and Security) framework for bioenergy policy evaluation. Though this study focusses on bioenergy policies, the framework is equally applicable to other renewable energy technologies or the combination of any two or more. Finally, the methodology for SWOT analysis of bioenergy market of Pakistan is discussed. The SWOT analysis evaluates the given situation, organization or proposal based on the factors affecting it either internally or externally. Internal factors are classified into two categories, strengths and weaknesses. Whereas, external factors are categorized into two categories, opportunities, and threats. Strengths and opportunities include factors that are favorable to the topic, while, weaknesses and threats include factors that can adversely affect the feasibility of the given topic.

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Chapter 4 Results and Discussion

4.1 Policy analysis and comparison

The framework for the analysis of policy employed a total of 16 qualitative indicators falling into five categories to compare renewable energy policies. All the variables hired are qualitative in nature. The framework for analysis was implemented on five of the recent policies of Pakistan concerning bioenergy. Which included Power policy 2002, RE policy 2006, Power cogeneration policy 2008, Bagasse cogeneration policy 2013 and Alternate and renewable energy policy 2019. When compared holistically, the upcoming ARE policy 2019, fulfils the most indicators/parameters discussed in Section 3.1.1. The ARE policy fulfilled a total of 12 indicators out of 16. Figure 4.1 presents the graphical comparison and Table 4.1 summarizes the policies based on the framework for policy analysis.

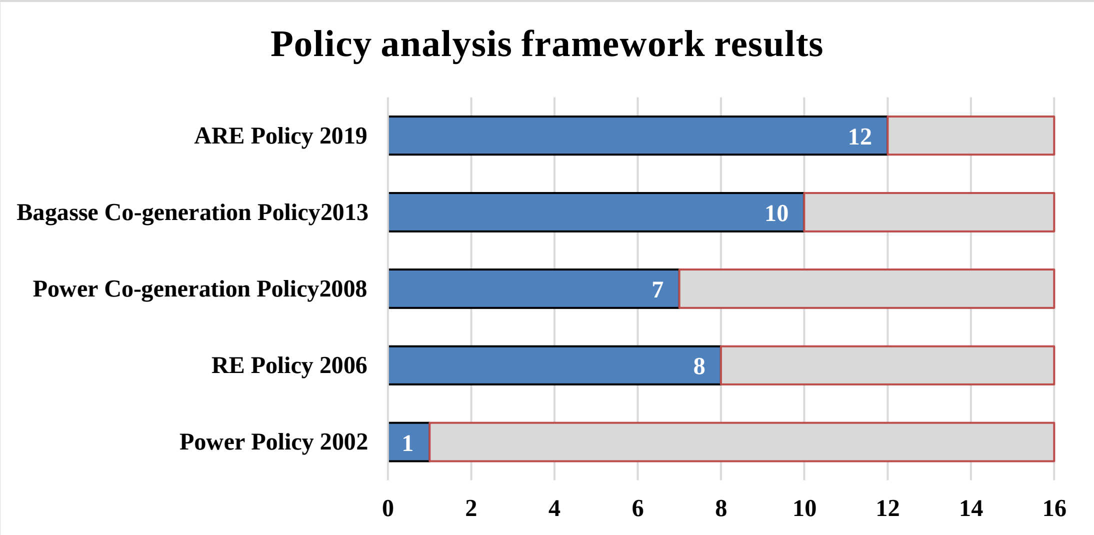

Figure 4.1 Policy analysis framework results

4.1.1 Fiscal Incentives

The following conclusions were drawn based on the study of the recent five policies: i) None of the policies discussed provides a grant for bioenergy or any other renewable energy technology, ii) Renewable energy policy (2006), provided tax incentives for power generation based on renewables, but the policy scope didn't include bioenergy. While Bagasse cogeneration policy (2008) provided with a 5% fixed customs duty on import of machinery required for the co-generation plants. The 5% customs duty was continued in the following policy i.e. Bagasse cogeneration policy 2013. Which was later altered, as the policy was added to RE policy (2006) as an addendum. Which meant, all the tax incentives of 2006 will be available for bagasse power cogeneration projects and other bioenergy projects like biomass and municipal waste. iii) Carbon credits were introduced by renewable energy policy (2006). Until 2013, such credits were not applicable to bioenergy projects. After the addition of bagasse cogeneration policy into RE policy (2006) as an addendum, bioenergy plants can apply for Carbon credits as well. iv) The new policy, ARE 2019, will provide some sort of feed- tariff to bioenergy projects. However, a new policy will provide FIT under the name Upfront tariff or Cost-plus tariff. NEPRA will decide on the provision of FIT. As per the policy, immature technologies will be eligible for the upfront tariff.

4.1.2 Public Finance

Surprisingly, all of the policies discussed fail to provide any investment to bioenergy producers or project. Same for loans and guarantees, none of the policies mentioned a single clause for the provision of public finances and guarantees by public institutions for sanction of loans and guarantees.

4.1.3 Regulatory Incentives

For the five policies under scrutiny for regulatory incentives following conclusions were drawn: i) No provisions for inclusion of bioenergy into the power generation portfolio [1]. ii) Renewable energy policy (2006) introduced net-metering for renewable energy projects, subsequently, other policies did the same as well. iii) Till 2013, energy banking was not applicable to bioenergy projects. iv) Bioenergy power plants were provided guaranteed power purchase after the promulgation of Framework for power co-generation in the year 2013.

4.1.4 Institutional and Political Feasibility

The presence of strong institutions like NEPRA and AEDB presents a strong case for the institutional feasibility of policy implementation. Power producers intending to use bioenergy first apply for the letter of intent (LOI) from AEDB and generation license from NEPRA. The country has seen an increased interest of investors in the bioenergy sector [2]. One thing odd is the lack of investor interest in power generation from municipal waste and agricultural residue.

Investors in the energy sector have been provided immunity to any of the changing political situation. RE policy (2006) and ARE policy (2019) were eloquent on the given issue. According to A.M. Khushk et. Al. [3], seventy per cent of sugar-mill owners have a sole proprietorship and sixty per cent of owners have family members who own a sugar mill. Thus, it can be concluded that there is a strong monopolistic stakeholder base. Finally, the dependability of the policy concept is robust enough for the policies discussed. As the world's largest biomass producers China, India, and Brazil have been exploiting the bioenergy potential for a long time [4], [5], [6].

Table 4.1 Comparison of energy policies for incentives in bioenergy sector

Policy evaluation parameters	**Power policy 2002**	**RE policy 2006**	**Power co-gen Policy 2008**	**Bagasse co-gen 2013**	**ARE Policy 2019**
Fiscal incentives (S)					
Grants	✕	✕	✕	✕	✕
Tax reductions/ exemptions	✔	✔	✔	✔	✔
Carbon Credits	✕	✔	✕	✔	✔
Feed-in tariff (FIT)	✕	✕	✕	✕	✔
Public finance (S)					
Investment	✕	✕	✕	✕	✕
Loan	✕	✕	✕	✕	✕

Guarantee	✗	✗	✗	✗	✗
Regulatory (S)					
Renewable Portfolio Standard /Quota obligation or mandate	✗	✗	✗	✗	✗
Net metering (also net billing)	✗	✓	✓	✓	✓
Banking	✗	✓	✗	✓	✓
Guaranteed power purchase	✗	✓	✗	✓	✓
Institutional Feasibility (S)					
Potential to implement policy	✗	✓	✓	✓	✓
Investor interest	✗	✗	✓	✓	✓
Political viability (S - R)					
Existence of stakeholder support	✗	✓	✓	✓	✓
Stability of stakeholder support	✗	✗	✓	✓	✓
Influence of stakeholder groups	✗	✗	✗	✗	✓
Dependability of policy concept	✗	✓	✓	✓	✓

R - Indicators effecting/relating Power Receiver

S - Indicators effecting/relating Power Supplier

✓ Discussed ✗ Not Discussed

4.2 Policy evaluation for their effectiveness/impact

To put the EE-S framework for policy evaluation into action, the recent policies of Pakistan are compared. The evaluation and comparison considered policies promulgated after 2002, till 2013. The time span was chosen to make sure the policies have reached their lifespan. The forthcoming ARE policy has been kept out deliberately, as it is not yet promulgated officially, and the measure of its effectiveness is a matter of future consideration. The data has been gathered using the following databases in the order of priority, International Energy Agency (IEA), World Bank, National Electric and Power Regulatory Authority (NEPRA), and Pakistan Bureau of Statistics (PBS). When compared based on the 10 quantitative variables, the latest policy that reached its life i.e. bagasse cogeneration policy of 2013 lead with the highest numbers in all categories. Table 4.2 tabulates the results collected for each of the parameters used in the policy evaluation framework.

Table 4.2 Energy Policy evaluation with respect to bioenergy

Indicator	Power policy 2002	RE policy 2006	Power co-gen policy 2008	Bagasse co-gen 2013
Contribution of bioenergy in Energy Security				
Installed capacity (MW)	0	23	105	301
Bio-electricity generation (GWh)	0	66.24	302.4	1060
Bioenergy share in TPES (%)	0	0.06	0.3	0.79
Environmental Impact of bioenergy generation				
Fossil fuels replaced (Petroleum Barrels)	0	129,400	590,740	2,071,000
Carbon Reduction (Mt. tonnes)	0	30,272	138,196	484,000

Economic Impact of bioenergy generation				
Employment	0	133	609	1746
Gross Income (Rs)	0	323	3.55	12.4
Import Reductions (Mill. USD)	0	12.897	57.88	134.41

4.3 SWOT Analysis of the bioenergy generation in Pakistan

4.3.1 Strengths

4.3.1.1 Presence of large biomass potential for bioenergy generation

As discussed in detail earlier in section 2.3, there is a large biomass availability to be used to produce bioenergy. The main usage of biomass today is in the form of firewood and animal dung. According to IEA's estimations, bioenergy contributed 33,736 KTOE to the total primary consumption of 95,660 KTOE for the year 2016. Whereas, in the case of modern bioenergy, power plants using sugarcane bagasse for energy generation, sold a total of 1,060 GWh of bio-electricity to the grid for the fiscal year 2017-18.

Apart from firewood and animal dung, there are other sources like agricultural residue, municipal solid waste, industrial waste (food and timber) and forestry residue. According to the study done by executing organizations to develop Biomass Atlas of Pakistan concluded a potential of 138.4 million metric tons of agricultural residue, including both the crop harvesting and crop processing residue. The maximum theoretical potential of generating energy from the agricultural residue stood at 510,828 gigawatt-hours of thermal energy. To put this amount into perspective, the total electricity generation stood at 133,615 gigawatt-hours for the year 2017-18.

4.3.1.2 Investor interest

There has been growing interest in bioenergy generation both at large and small scales. As discussed in Section 2.5, there has been a lot of work being done for small scale bioenergy plants, especially biogas plants based on anaerobic technology. Furthermore, at large scale sugar mills used to derive process heat from sugarcane bagasse for a long time. With the passage of time, the sugar mills are moving towards high-pressure boilers to be used for power generation along with heat for different industrial uses.

The investor interest was evidenced when renewable energy policy lacked bioenergy in its scope, and policymakers had to come with national policy for power co-generation in 2008 to cater to the investors in the bioenergy sector. According to NEPRA's state of industry report of 2018, a total of 913 MW of bioenergy capacity is under the listening and implementation process, to be completed by 2021. While the total bio-electricity sold to the national grid stood at 1060 GWh. The same report stated a total of 339 MW of captive power generation capacity.

4.3.1.3 Comparatively equal initial investment cost with fossil fuel-based plants

While other renewable technologies are still at a disadvantage when compared to conventional fossil fuel-based power plants in terms of initial investment, for bioenergy it is a different case. Thermal based bioenergy plants can utilize the currently available technologies for thermal power plants, with little or no modification. Secondly, the current coal and oil-based power plants can generate power using biomass as a fuel, with small modifications in the combustor of the power plant.

4.3.1.4 Profitability of new power plants and rate of returns

The major factor for a new power plant to be implemented is its profitability and a feasible rate of return. For bioenergy, especially the industrial based thermal plants have been lucrative. This is evidenced by the statistics of NEPRA, where captive power plants (based on biomass) have been consistently supplying energy to the national grid. Furthermore, the tariff determination process for the new power plants by NEPRA considers the following elements to make sure profitability: Fuel Cost, Variable O&M (Local + Foreign), Fixed O&M, Insurance, Working Capital, Debt Service and Return on Equity.

4.3.1.5 Tax reductions and exemptions for new power plants

Pakistan being a developing agrarian country imports most of its machinery from other countries. This includes machinery for power plants as well. Since 2002's power policy, all the sub-sequent energy policies have made provisions for fixed custom duty at 5%, which runs more than a hundred per cent for other machinery imported.

Secondly, renewable power generation is provided concession in sales tax and other taxes when they provide electricity to the national electricity grid.

4.3.1.6 Presence of policy instruments to encourage bioenergy generation

In 2006, the government of Pakistan through renewable energy policy introduced different policy instruments to encourage renewable energy generation in Pakistan. Which included Carbon Credits, Net metering, Energy banking and Guaranteed power purchase for renewable energy power plants.

Carbon credits are credits given to the power producer, mostly under the Clean Development Mechanism (CDM). Whereas, under net metering, anyone with surplus power (renewable in this case) is allowed a two-way flow of energy between the energy dispatch company and power producer (Captive). While, energy banking allows a business or a person to invest in a renewable energy plant, elsewhere than his residence. Such an investor is privileged to access energy at his choice of location in the same amount as his power plant produces. Guaranteed power purchase agreements are made to prioritize and ensure a buildup of the renewable energy sector. This incentive guarantees the purchase of every unit of power produced by the RE producer.

4.3.2 Weaknesses

4.3.2.1 Low energy density of bioenergy fuels

Biofuels generally have low energy densities when compared to traditional fuels like coal and gasoline [7], [8]. This makes it difficult for investors to shift reliance on traditional fuels to biofuels. This is most obvious for the biomass pellets and briquettes. When compared to calorific value and energy density (energy per unit of mass), fossil fuels are ways ahead than biofuels.

For example, the calorific value of biogas ranges between 5 and 6.672 kWh/m^3 [9], while the calorific value of natural gas is 11.7 kWh/m^3. While for ethanol calorific value is 26.88 MJ per kg and gasoline's calorific value is 46.4 MJ per kg[10].

4.3.2.2 Biomass supply chain

Due to the seasonality of biomass production, a sustainable biomass supply chain is difficult to maintain. Whereas, the collection of biomass is another issue, according to [11] the collection and handling of biomass are not done properly. Secondly, lack of pelleting and briquetting technologies also leads to wastage of biomass, especially agricultural residue.

Secondly, storage is another issue in the biomass supply chain. Long term storage is required due to the seasonality of biomass production. This further adds to the fuel prices, thus adversely impacting the sustainability of the sector. While traditional fuels like coal and oil have higher mass densities requires lesser space, biomass requires more space for storage, putting it at a disadvantage when compared to traditional fuels.

4.3.2.3 Lack of infrastructure to integrate bioenergy plants with the national grid

The feasibility of locating a bioenergy plant is highest near the agricultural fields, which is validated for Pakistan by Biomass Atlas of Pakistan and another study by Markus Tum et. al. [12], [13]. While, such agricultural fields lack access to the national grid, due to low population density [11], [14]. This makes it difficult for the investors to get access to the national grid, this further discourages investors who want to work as independent power producers.

4.3.2.4 Low-quality research nationally

Despite the presence of different institutes and organizations dedicated to carrying out research in the renewable energy sector, there has not been a major application of the works carried out by such organizations. Organizations include PCRET, PCSIR, PSO and academic institutes in different public and private sector universities.

For example, PCRET has been working on moveable and foxed dome biogas plants for a long time. Despite the successful design and fabrication of the biogas plant, it has not been commercialized yet. Similarly, Pakistan state oil financed a project called E-10 gasoline pilot project, but no provisions have been made for ethanol blending with gasoline. Another project by AEDB identified crops like Pongamia pinata, rapeseed and castor bean for the production biodiesel. But no progress has been shared by AEDB regarding this project [15].

4.3.3 Opportunities

4.3.3.1 Large potential of underutilized biomass

There are multiple sources of biomass available for the generation of bioenergy in Pakistan. which includes agricultural residue, livestock manure, municipal solid waste, industrial waste (food and timber) and forestry residue.

There remains a large part of the potential of biomass not being utilized yet. In the case of agricultural residue its only sugarcane bagasse. Whereas, there are other crop residues readily available for bioenergy generation. Details of the different agricultural residues are tabulated in Table 4.4, along with energy generation potential. Whereas there is not a single power plant utilizing municipal solid waste in the country for power generation. According to biomass atlas, energy generation potential from MSW stands at 360 MW for 12 of the dump yards only [12]. While A. Raheem et. al. [16] estimated a total of 242-million-m^3 of biogas generation from MSW in the ten major cities of Pakistan.

Table 4.3 Bioenergy generation potential from agricultural residue

Crop	Residue type	Maximum potential (Theoretical)		Maximum potential (Technical)	
		Annual residue production (Mill. tons)	Total Energy content (GWh_{th})	Annual residue production (Mill. tons)	Total Energy content (GWh_{th})
Cotton	Stalks	49.41	206020	6.1	25073
Wheat	Straw	34.62	138325	6.51	25952
Rice	Straw	16.74	58138	8.33	28848
Sugarcane	Stalk and leaves	7.81	29835	3.51	13397
Maize	Stalk and leaves	5.32	24124	0.84	3619
Total		**113.87**	**456,442**	**25.19**	**96,889**

4.3.3.2 Dedicated energy crops and marginal crops

Crops like sugarcane and corn have been successfully grown around the world for biofuels and bioenergy generation. But these crops, categorized as first-generation biofuels, compete with food sources and are thus regulated to ensure food security. Therefore, there has been increased interest in non-food crops, categorized as second-generation biofuels, for the generation of bioenergy [17]. The advantages that these crops have over food crops such as corn are: they have less yearly input requirements, they require lesser fertilizers and herbicides than food crops, biomass production is high even with inadequate inputs, such crops have the potential to withstand different environmental conditions.

Energy crops like Industrial hemp [18], Jatropha [19], Taramira (Eruca sativa L.) [20] and Microalgae [21] have been studied by different researchers for their production in Pakistan. For instance, according to [18], industrial hemp can provide 413 Kg of ethanol, 185 Gigajoules of biogas and 105 Gigajoules of solid fuel per acre of cultivation. These crops, in the long run, can be utilized to produce bioethanol and biodiesel to be blended with petroleum fuels, thus diversifying the energy mix.

4.3.3.3 Opportunity to fulfil INDCs

INDCs are the intended nationally determined contributions to limit global temperature rise. Pakistan became the part of the Paris Agreement in the 22nd Conference of the Parties (COP 22) of the UNFCCC (United Nations Framework Convention on Climate Change). According to the INDC statement submitted by the Ministry of Climate Change to UNFCCC, Pakistan will reduce its greenhouse gas emissions by 20%. Therefore, by the addition of more renewable energy sources into the energy mix, Pakistan can reduce its carbon footprint and fulfil the commitments made to the UNFCCC. Bioenergy along with solar and wind can play a substantial role in reducing the total GHG emissions [22], [23] and shifting the heavy reliance on fossil fuels.

4.3.3.4 Economic development

Investment in bioenergy technologies can contribute to regional and national economic development. This may be through business growth, and employment generation, reduction in energy imports, direct and indirect economic impact on external trade and gross domestic product [24].

As Pakistan relies on imported petroleum products for most of its energy needs, bioenergy can best help in reducing this reliance and add to the security and diversification of energy supply. This may be realized through the replacement of biomass pellets in coal and oil firing power plants, gasoline with bioethanol, and diesel with biodiesel. Whereas, farmers and industry owners can add to their incomes by utilizing the waste not being used currently.

4.3.3.5 Social development

In several ways, the social impacts of investment in local bioenergy can significant. Two of the major ways include those relating to an increased standard of living and those that contribute to increased social cohesion and stability. The standard of living refers to a household's consumption level or its level of fiscal income. However, there are other factors that contribute to a person's standard of living, which cannot be quantified in economic terms. These include factors such as access to education, employment opportunities, a clean environment and healthcare [24].

Employment can be through construction, maintenance and operation of bioenergy plants. The increased demand for biomass through the Construction of power plants leads to further income and employment opportunities in biomass production and supply chain. Moreover, the addition to the net employment and income-generation could help to stem adverse social and cohesion trends (i.e. unemployment, rural to urban migrations). Furthermore, economic activity supports related industries and employment. Finally, it is possible to achieve sustainable rural development by engaging the key stakeholders in the bioenergy sector.

4.3.3.6 Off-grid power provision

While the electrification rates are encouraging, there still remains a large population without modern energy provisions. According to IEA 23% of the population has no access to electricity and 53.7% lack provisions to clean cooking fuels like natural gas. The disparity in access to modern energy sources can be mitigated through small and medium scale off-grid power plants.

Instead of laying expensive grid lines and transmission systems, bioenergy plants utilized to provide electricity and clean cooking fuels to the underprivileged. There have been successful attempts to provide biogas using anaerobic digestion technologies in Pakistan, as discussed in detail in section 2.5. Along with biogas plants, thermal power plants based on biomass can be helpful in providing electricity. As in India Husk Power Company successfully electrified more than 250 villages [25]. The same can be replicated in Pakistan keeping in mind the similar economic and social situation.

4.3.4 Threats

4.3.4.1 Low knowledge of bioenergy technologies among the populace

One of the major issues in the bioenergy market is the lack of trust and awareness of bioenergy technologies among the general public [26]. Farmers are reluctant to adopt bioenergy technologies because of previously held mindset regarding bioenergy. Rural areas in Pakistan apply animal manure directly to the agricultural fields, which can be used to produce biogas and use the leftover slurry as a bio-fertilizer. But farmers don't realize this potential for biogas and fertilizer. While, others find it expensive to install and cumbersome to operate and maintain [11], [27].

4.3.4.2 Lack of policy instruments to encourage bioenergy generation

The present renewable energy lacks some of the major policy instruments to encourage investments in bioenergy generating plants. This includes the renewable portfolio standard (RPS) and feed-in tariff (FIT). Policy instruments like FIT and RPS have been proved effective to drive investment into renewable energy and support the burgeoning sector [28]. In 2019, the government of Pakistan came up with a new policy for renewable and alternative energy sources. Though this policy has not been officially promulgated yet, it mentions a provision for grants, similar to FIT, while the new policy is still silent on making provisions for the implementation of renewable portfolio standards for current power producers.

4.3.4.3 Long duration for registration and tariff determination of new power plants

There are specific institutions like AEDB and NEPRA to deal with new registrations for the bioenergy (renewable) power plants. The problem is the long and cumbersome process of solicitations, licensing and tariff determinations [29]. While large investors hire legal experts to deal with registration processes, small and medium-scale power producers intending to enter into the energy market get discouraged by such long processes. The study of the policy documents reveals that it may take up to 465 days to complete the process, which doesn't include the feasibility study period. Thus, this issue needs to be addressed to attract more investors into the bioenergy market.

4.3.4.4 Low level of cooperation between state institutions

The following state institutions deal with matters related to energy generation in Pakistan, the Ministry of Energy (Power and Petroleum Division), Alternative energy development board (AEDB), PPIB and PCRET. According to Usman Zafar et. al [1], there remains a lack of cooperation between regulatory institutes and ministries. Another example of the absence of collaboration is between the PCRET and Hydrocarbon development institute of Pakistan (HDIP). HDIP, which was tasked to work on different blends of biofuels and petroleum products [15], could collaborate work with PCRET in developing such biofuels from locally available biomass resources. The lack of cooperation could lead to the repetition of such projects, and loss of time and public funds.

4.3.4.5 Low level of academia and industry linkages

As discussed before in 4.2.1, there are academic institutes working carrying out research in the bioenergy sector. One the reason for the low quality of such research is the lack of industry-academia linkages [30]. The research work carried out by academic institutes rarely gets commercialized. This is in contrast with the developed nations, where the commercialization of academic research is thought to be the main tool for industrial growth [31].

The major challenges in linking academia and industry in Pakistan are limited involvement of Government and related ministries in the development of sciences and technology, poor administration and improper execution, budget allocations, cut-downs in the funding, low international marketing and national utilization of the product. Another major challenge to industries is the consumer’s stance towards imported products and lack of trust in local brands [32].

4.3.4.6 Lack of skilled labour force to implement, run and maintain bioenergy technologies

One of the reasons highlighted by Umar K. Mirza [15] for the failure of different biogas (bioenergy) dissemination programs is the lack of a skilled workforce to maintain and operate these plants. The same study by U.K. Mirza further states the lack of institutes to train people for such tasks, both in the public and private sectors.

The lack of such a workforce has been attributed to low demand and low activity in this sector [11], which is due to the lack of knowledge among the general population. Search on the internet using general search engines and academic search engines revealed only two such institutes providing post-installation services to bioenergy power plants. Furthermore, the state institute tasked with research and development in the renewable energy sector has no such program, apart from a few seminars arranged on renewable energy technologies.

Table 4.4 Energy Policy evaluation with respect to bioenergy

Strengths	Weaknesses
• Presence of large biomass potential for bioenergy generation • Investor interest • Comparatively equal initial investment cost with fossil fuel-based plants • The profitability of new power plants and the rate of returns • Tax reductions and exemptions for new power plants • Presence of policy instruments to encourage bioenergy generation • Cooperation between federal and provincial governments • Bioenergy an alternative to petroleum based fuels • Energy security through bioenergy	• The low energy density of bioenergy fuels • Biomass supply chain • Lack of infrastructure to integrate bioenergy plants with the national grid • Lack of policy instruments to encourage bioenergy generation ○ The feed-in tariff, Renewable portfolio standard • Low-quality research nationally
Opportunities	**Threats**

• The large potential of underutilized biomass
• Energy and marginal crops
• Opportunity to fulfil INDCs
• Economic impacts
  ○ Source of income
• Social impacts
  ○ Employment generation
• Off-grid power provision
• Biomass utilization in cogeneration plants.
	• Lack of trust in bioenergy technologies viability
	• Long duration for registration and tariff determination of new power plants
	• Low level of cooperation between state institutions
	• Low level of academia and industry linkages
	• Lack of skilled labour force to run and maintain bioenergy technologies

4.3.5 Recommendations

4.3.5.1 Provision for Financial and Regulatory incentives

The current policy for the bioenergy sector lacks regulatory and financial incentives to attract investors. Renewable portfolio standard (RPS), Feed-in tariff, two of the common regulatory tools present in most countries (developed and developing), should be offered along with the bioenergy generating plants.

As discussed, earlier, financial incentives are absent in energy policy to attract investors. In countries like Germany, U.K., Sweden and Italy investments and subsidies have proven to be effective in developing bioenergy [33]. This is the same for emerging countries like India and China, which can be easily replicated in Pakistan as well. Furthermore, grants for new power producers should be allocated in federal and provincial budgets.

4.3.5.2 Improvement in Institutional process

While the results of the policy analysis framework were positive for institutional feasibility (Section 4.1.4), the registration and tariff determination process for new power plants is cumbersome. Currently, AEDB, PPIB, and NEPRA deal with registration and tariff determination process. AEDB deals with power projects of less than 50 MW, whereas, PPIB deals with projects more than 50 MW of capacity. Projects that get accreditation from AEDB or PPIB are eligible for tariff determination by NEPRA. The study of the policy documents reveals that it may take up to 465 days to complete the process, which doesn’t include the feasibility study period. Thus, this process needs to be eased to attract more investors into the bioenergy market. While on paper the government has categorized AEDB and PPIB as one window operation facility, there need improvements in the process efficiency.

4.3.5.3 Enhance Stakeholder confidence and involvement

One of the important steps in policymaking is to enhance stakeholder’s confidence in the policy [34]. Furthermore, involving stakeholders in the policy-making process has emerged as early as two decades ago [35]. Studies have found that for better stakeholder’s involvement leads to a better appreciation of larger community among the public and a way to tackle deterioration in public trust and a tool for transformative social change [36].

Pakistan needs to enhance stakeholder confidence and involvement in policymaking. The bureaucracy of the country needs to include members both from the public and private sectors as well. Private institutes like Pakistan Sugar Mills Association, Livestock Farmers & Breeders Association and other relevant bodies can better help in making an effective policy and implementation.

4.3.5.4 Long term planning and diversification

Some of the energy policies in the past have come out of desperate attempts to mitigate the energy crisis, while others were politically driven [29]. The same was the case for the cogeneration policies for sugar mills. Ad-hoc policymaking fails to deliver a sustainable energy mix. Therefore, policymakers need to take long term planning into consideration before enacting any policy. Work needs to be done beforehand to look for sustainable options. Energy modelling tools like MESSAGE, MARKAL-TIMES or EnergyPlan can be used to forecast for a sustainable energy mix of renewables with conventional sources of energy.

Successful energy policy can be devised through the collaboration of policymakers, stakeholder and academia [37]. Furthermore, diversification of energy sources is the need of time. Policymakers have to expand the domain of bioenergy from bagasse to other bioenergy resources like agricultural residue, municipal solid waste, and industrial waste.

4.3.5.5 Capacity building in the bioenergy sector

Pakistan relies on foreign countries for the production of heavy machinery, which includes machinery for power generation. This gap makes it difficult for prospective power producers to enter the energy market. Moreover, the country faces a lack of skilled labour for maintenance of the power generation systems [38].

To cover this gap, the government of Pakistan needs to enable the local industry to enhance its capacity to manufacture machinery indigenously. This can be done through technology transfer with nations having a sophisticated industrial base. Also, foreign companies specializing in power machinery can be incentivized to invest in manacling plants in Pakistan.

4.3.5.6 Awareness programs for rural communities

The government of Pakistan did some pilot projects to promote bioenergy technologies in the past but failed miserably to do so. This was due to a lack of awareness among rural communities. Furthermore, the executing agencies failed to educate the people in terms of the socio-economic benefits of these plants. Also, the initiatives failed to train the locals in skills such as maintenance and repair of these plants.

Therefore, there need to be more awareness campaigns first. Where people are made aware of the socio-economic benefits of bioenergy technologies. Such campaigns need to address the misconceptions like investment risks, uncertainty about renewable energy, high capital costs.

4.3.6 Comparison of SWOT analysis results and questionnaire results

Second step in carrying out SWOT analysis is to substantiate the results of SWOT analysis and to validate the objectivity of the analysis. A questionnaire was formed using the questions of SWOT analysis and shared with stakeholders in energy sector of Pakistan. the questionnaire used a Likert scale approach to scale responses. With 0 being low/negative and 10 being high/positive. Table 4 compares the opinion of stakeholders in energy sector and authors analysis of the given questions. Complete questionnaire responses are attached in the appendix of the document. The The response of experts from energy industry and my own analysis was similar. For 16 questions response matched my analysis, whereas for 5 questions there was slight difference of opinion.

Table 4.5 Comparison of SWOT analysis for subjectivity

Question	Self-Analysis	Questionnaire response (Average rating)
-Presence of the natural conditions for the development of bioenergy sources	High	High (9)
-Public stance towards bioenergy, positive or negative.	Negative	Moderate (5)
-The current level of knowledge of bioenergy technologies among people.	Low	Low (4)
-Interest among investors and authorities in the development of bioenergy.	High	Moderate (6)

-Presence of skilled labour force to implement bioenergy technologies.	Low	Low (4)
-Initial investment costs and operations and maintenance costs.	Moderate	Moderate (6)
-The profitability of new power plants and the rate of returns.	Moderate	Moderate (7)
-The economic impact of new bioenergy plants.	High	High (9)
-Social impact of new bioenergy plants.	High	High (9)
-Positive impact on the environment of Bioenergy generation.	High	High (9)
-Potential power plant sites and their feasibility to connect to the national grid.	Low	Moderate (6)
-Potential for power provision to Off-grid population.	High	High (9)
-Competition with traditional energy sources like coal and petroleum products.	Moderate	Moderate (7)
-Security of biomass supply chain.	Low	Moderate (5)
-Government grants, subsidies, and tax reductions or exemptions.	Moderate	Moderate (5)
-Policy instruments to encourage existing power producers to shift towards bioenergy	Moderate	Moderate (6)
-The coherence of energy, environmental and climate policy.	Moderate	Moderate (6)
-Ease of registration and facilitation for new power producers.	Low	Low (4)
-Presence of cooperation within state institutes and with private organizations.	Low	Low (4)
-Level of cooperation between federal and provincial governments and institutes.	Low	Low (4)
-The current state of quality of research in bioenergy, nationally.	Low	Moderate (5)

Summary

This chapter discussed in detail the results of the research study. Firstly, the frameworks developed for policy analysis and evaluation were put into action by employing them to analyze and evaluate the last five energy policies of Pakistan. The framework for the analysis of policy employed a total of 16 qualitative indicators falling into five categories to compare renewable energy policies. All the variables hired are qualitative in nature. The framework for analysis was implemented on five of the recent policies of Pakistan concerning bioenergy. Which included Power policy 2002, RE policy 2006, Power cogeneration policy 2008, Bagasse cogeneration policy 2013 and Alternate and renewable energy policy 2019. When compared holistically, the upcoming ARE policy 2019, fulfils the most indicators/parameters. The ARE policy fulfilled a total of 12 indicators out of 16. Secondly, the renewable policy effectiveness index developed in this study was applied for the last three policies of Pakistan. The framework developed for policy evaluation into action, the recent policies of Pakistan are compared. The evaluation and comparison considered policies promulgated after 2002, till 2013. The time span was chosen to make sure the policies have reached their lifespan. The forthcoming ARE policy has been kept out deliberately, as it is not yet promulgated officially, and the measure of its effectiveness is a matter of future consideration. When compared based on the 10 quantitative variables, the latest policy that reached its life i.e. bagasse cogeneration policy of 2013 lead with the highest numbers in all categories. The second part of the study was to do a comprehensive SWOT analysis of bioenergy generation in Pakistan. In this part, the state of bioenergy generation in Pakistan was studied for its strengths, weaknesses, opportunities, and threats. Finally, a set of recommendations was presented for better utilization of the bioenergy resources in the country and the development of the bioenergy sector.

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Chapter 5 Conclusions

Changing climate and its effects on the global ecosystem have tempted humankind to move from conventional fuel sources to renewable energy sources. Bioenergy leads in terms of use among other renewable energy sources globally. Despite being dependent on energy imports Pakistan has never utilized its bioenergy potential to its fullest. This shortcoming has been related to different factors, the common being the policymaking and its implementation. This study tried to uncover the recent police for their merits and demerits, which lead to the creation of two frameworks (Framework for analysis policy and EE-S (Environment, Economy, and Security) framework for policy evaluation.) and a policy effectiveness indicator. The frameworks were applied to analyze and evaluate the recent bioenergy policies of Pakistan. The following conclusions were drawn for the recent bioenergy policies.

- Policies have evolved for better in recent years, both in terms of policy options and their effectiveness.
- Among three of the recent policies (RE policy 2006, Cogeneration policy 2008 and Bagasse power cogeneration policy 2013), the recent came up with the greatest number of parameters fulfilled in the policy analysis framework.
- Policymakers have adopted the following bioenergy driving factors into the policies: Tax reductions and exemptions, Carbon credits, Net metering, Energy banking, and Guaranteed power purchase.
- Furthermore, there are positive indications in terms of Institutional feasibility, Investor interest and Stability of stakeholder support.
- The policymakers failed to provide grants for new power plants, investments or loans from public finances, guarantees and renewable portfolio standards for existing IPPs
- The outlook for the new policy i.e. Alternate and renewable energy policy seem bright. But still, the new policy fails to set targets for bioenergy installation and share in the energy mix.

The second part of the study did a detailed SWOT analysis of the bioenergy market of Pakistan. Along with major strengths and opportunities in the bioenergy market of Pakistan, the study analyzed the factors that are weaknesses in the market and threats that may hamper the development of the bioenergy market. The following conclusions were made from the SWOT analysis of bioenergy generation in Pakistan.

- Strengths: Presence of large biomass potential for bioenergy generation, Investor interest Comparatively equal initial investment cost with fossil fuel-based plants, Profitability of new power plants and rate of returns, Tax reductions and exemptions for new power plants, Presence of policy instruments to encourage bioenergy generation, Bioenergy an alternative to fossil fuels, and Energy security through bioenergy.
- Opportunities: Large potential of underutilized biomass, Potential for Energy and marginal crops, Opportunity to fulfil INDCs, Employment generation, Off-grid power provision, and Biomass utilization in cogeneration plants.
- Weaknesses: Low energy density of bioenergy fuels, Biomass supply chain, Lack of infrastructure to integrate bioenergy plants with the national grid, Lack of policy instruments to encourage bioenergy generation, and Low-quality research nationally.
- Threats: Lack of trust in bioenergy technologies viability, the Long duration for registration and tariff determination of new power plants, Low level of cooperation between state institutions, Low level of academia and industry linkages, Lack of skilled labour force to run and maintain bioenergy technologies.

Based on the study done for the policy situation and bioenergy market's standings, the study suggests the following recommendations for better policymaking and development of a sustainable bioenergy generation in Pakistan.

- Provision for financial and regulatory incentives in the upcoming policy.
- Improvement in registration and tariff determination process.
- Enhancement in stakeholder confidence and involvement in policymaking.
- Long term planning and diversification of bioenergy resources.
- Capacity building in the bioenergy sector.
- Awareness programs for rural communities on the usage of modern biomass and bioenergy.

Appendix I

Table A.1 Initial selection of parameters for policy analysis

Fiscal

- Accelerated Depreciation Tax Benefit
- Capital subsidy or rebate
- Investment or production tax credits
- Energy Production payment
- Grant
- Carbon Credits
- Tax reduction/ exemption
- Feed-in-tariff/ premium payment

Public finance

- Investment
- Guarantee
- Loan
- public procurement

Regulatory

- Clear target for technology deployment
- Priority access to the network
- Power Purchase Agreement
- Electric utility quota obligation
- Net Metering
- Tradable REC/Green Certificate
- Renewable Portfolio Standard
- Energy Banking
- Tendering/ bidding

Institutional

- Institutional process
- Institutional Monitoring system
- Investor facilitation
- Quality of stakeholder Communications
- Human capital
- Resources available to staff
- Regulatory institutions
- Regulatory process
- Resource availability monitoring process
- Technology development
- Deployment record

Political

- Potential to implement policy
- Dependability of policy concept
- Existence of stakeholder support
- Stability of stakeholder support
- Influence of stakeholder groups
- The credibility of the policy
- Political appropriateness and acceptability of new development
- Sufficiency of resources
- Ownership of policy
- Investor interest
- Wider perceptions of the national institutional environment

Appendix II

Journal Paper

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A comparison of Energy Policies of Pakistan and their impact on Bioenergy development

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Abstract

Worldwide modern-bioenergy is getting more attention in terms of policy-support and deployment. Whereas, in Pakistan, this resource is not being used to its fullest. Though traditional biomass is being used by most of the rural population, but the use of modern biomass as an energy source is dismally low, which is a result of poor policymaking and its implementation. During the 1970s the first initiative was taken for the development of small scale (household/community level) bioenergy projects in Pakistan. Later, policies were enacted to exploit the bioenergy resources, especially bagasse-powered bioenergy generation. This study reviewed those initiatives and policies for their effectiveness in the development of bioenergy in Pakistan. Policies are compared for different aspects, including regulatory, fiscal, political and institutional. Furthermore, effectiveness is compared in terms of energy security, environmental impact, economic impact, and energy equity. The comparison has been made based on a total of 26 parameters. Moreover, two of the neighboring countries, China and India, were reviewed for the sake of knowing the country's standings, in terms of policies and initiatives taken for the development of bioenergy, internationally. Finally, the study presents the challenges and recommendations for policy-making in Pakistan, for maximum exploitation of bioenergy.

Keywords: *Bioenergy, Bioenergy Policy, Bioenergy Policy Evaluation, Pakistan*

Abbreviations

AEDB	Alternative energy development board
ARE	Alternative and renewable energy
CDM	Clean development mechanism
DGNER	Directorate general of new and renewable resources
ECC	Economic coordination committee
EIA	Energy information agency
FIDA	Foundation for Integrated Development Action
HEC	Higher education commission
ICB	International competitive bidding
IEA	International energy agency
IPP	Independent power producer
MNRE	Ministry of new and renewable energy (India)
NBM	National biofuel mission
NEPRA	National electric power regulatory authority
NGO	Non-governmental organization
PCAT	Pakistan council of appropriate technology
PCRET	Pakistan council of renewable energy technologies
PDBP	Pakistan domestic biogas program
PDDC	Pakistan dairy development center
PSDP	Public sector development program
PV	Photo-voltaic
RE	Renewable Energy
RET	Renewable energy technology
RSPN	Rural support program network

PPIB	Private power infrastructure board
TOE	Tones of Oil Equivalent

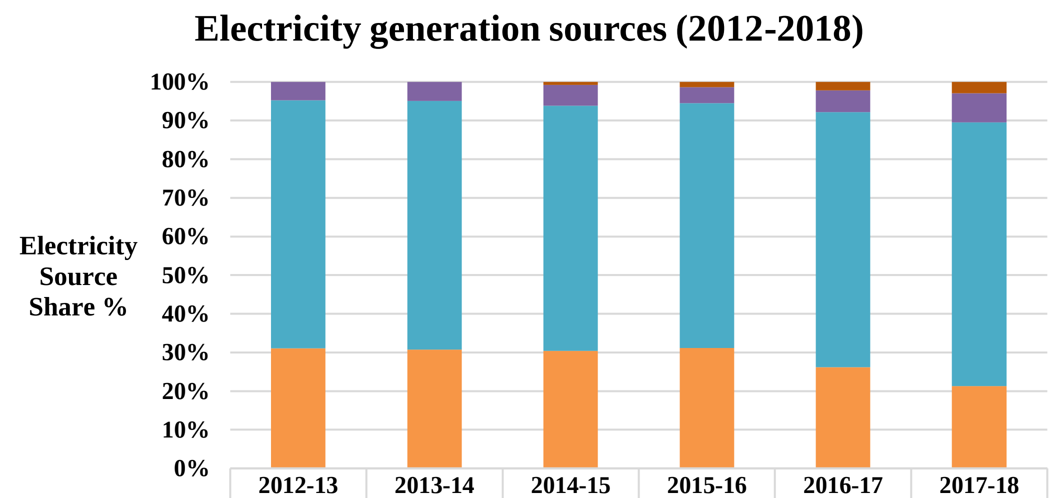
1 Introduction

The prosperity of a country is often related directly to the presence of a robust energy supply system in the given country (Rafique et al., 2017; Zysman and Huberty, 2010). An energy supply system can be robust when it is able to withstand the changes in the global energy scenario (Lucas et al., 2016). Such a system relies on indigenous resources for energy supply. In earlier times presence of coal reserves bolstered a country's energy supply, while currently its oil and gas. Though fossil fuels have a major share in global energy supply (Kang et al., 2018), the trend is changing nowadays, the world is shifting towards renewable energy sources (Kraemer and Stefes, 2016; Tollefson, 2018), to mitigate the effects of using fossil fuels. The effects include emission of harmful gases and particulate matter, which in long term may cause multiple problems for mankind (Atilgan and Azapagic, 2015; Höök and Tang, 2013; Machol and Rizk, 2013; Nicoletti et al., 2015).

Pakistan is a developing country, where the situation of energy supply is crippled due to problems like fragile infrastructure, theft, losses and ad-hoc provisions for energy supply (Gondal et al., 2018; Ishaque, 2017; Rukh et al., 2016; Zameer and Wang, 2018). There is somehow improvement in the power generation capacity over the last five years, but this addition is in thermal-based power generation. The exploitation of renewable energy sources remains dismally low and there remain areas with no access to modern energy supplies (Nawaz and Alvi, 2018). For the year 2017-18 electricity generation from all renewables was 3% and for bioenergy, it was a mere 0.65% of total electric energy generation (Hydrocarbon Development Institute of Pakistan, 2018). Figure 1 shows the share of electricity generation of different sources from 2012 to 2018.

Due to the lack of indigenous resources, Pakistan relies on imported fossil fuels to satisfy its energy needs. According to the Ministry of Energy (Hydrocarbon Development Institute of Pakistan, 2018), Pakistan relies on fossil fuels, including imported and domestic, for 88% of its total primary energy supply. Figure 2 shows the total primary energy supplies for the year 2017-18. Most of the supplies are subsidized due to bilateral agreements. This puts Pakistan in a precarious situation, any international embargo can shatter the energy security of Pakistan. Therefore, Pakistan needs to diversify its energy supplies. This can be done through the utilization of indigenous resources, especially renewable energy resources so that the country moves towards a sustainable and cleaner energy future. Pakistan has a very large untapped potential of renewable energy, which includes energy from solar, wind and biomass.

Bioenergy is one of the leading primary energy supplies in the world (Von Cruz and Dierig, 2015). According to IEA's world energy outlook (International Energy Agency, 2018) modern bioenergy provided 727 MTOE (5.2%) and traditional biomass with 658 MTOE (4.7%) globally against a sustainable technical potential of 1194 MTOE (Gregg and Smith, 2010). For Pakistan share of modern bioenergy for the year 2017 was 67543 TOE, which was mere 0.65% of total energy generation for the given year.



	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Renewable			802	1,549	2,668	3,857
Nuclear	4,553	5,090	5,804	4,605	6,999	9,880
Thermal	61,711	66,707	67,886	70,512	81,268	89,614
Hydel	29,857	31,873	32,474	34,634	32,183	27,925

Figure 1 Electricity Generation 2012-2018 (Source: Pakistan Energy Yearbook)

Though biomass has been the traditional fuel for the masses since the inception of Pakistan, modern usage of biomass for bioenergy remains very low. Over the history of the country, different policies and initiatives have been taken to exploit the bioenergy potential. A closer look at literature gives the decade of 1970s as the time when Pakistan for the first time focused on exploiting bioenergy through modern energy conversion techniques. This can be related to the uncertainty in global energy markets and rising oil prices of that time. There was no official policy made at that time, but different initiatives were taken via the formation of new public sector organizations. It was in 1994 when Pakistan’s energy policy included the bioenergy in its scope. Though the results were dismal for the usage of biomass for bioenergy till 2006. In 2006 Pakistan came up with a dedicated policy for the development of renewable energy in the country (Zafar et al., 2018). The prime focus of the policy was on wind and solar energy, whereas bioenergy was categorically kept out from the policy. Then in 2008 PPIB came up with National policy for power cogeneration by sugar industries. This was a first step towards exploiting Pakistan's bioenergy potential at the national level. The policy was revised in 2013 as Framework for Bagasse power cogeneration, while this time AEDB on board. In the same year i.e. 2013, the RE policy of 2006 which now includes bioenergy in its scope was further extended to for five years. Making it applicable until March 2018. Therefore, a new policy should have been formulated in 2018, but there was silence from policymakers till last month (i.e. June 2019). Though not promulgated officially, policy under the name of Alternative and Renewable energy Policy’s draft has been shared among stakeholders. The new policy intends to take some bold steps in increasing the share of renewable energy in total energy supplies.

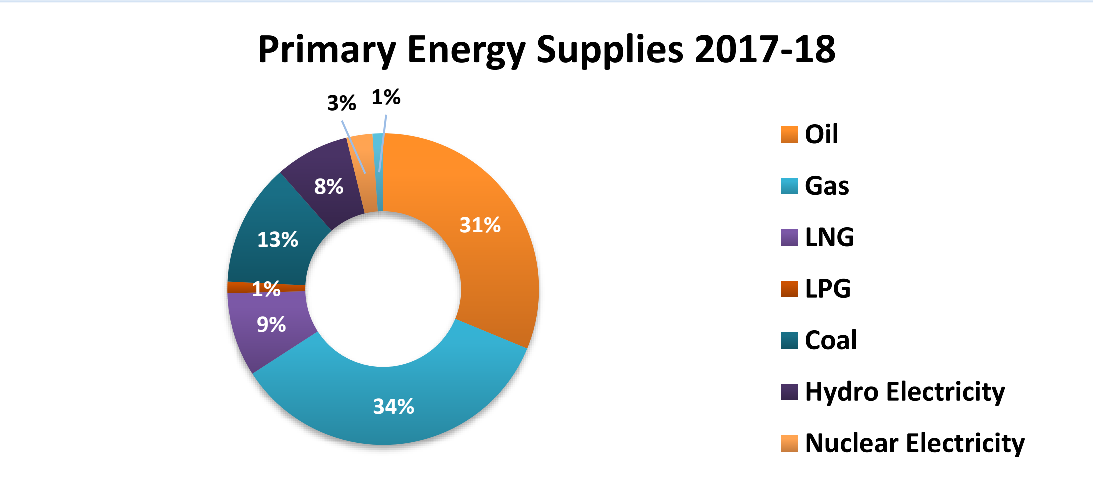


Figure 2 Primary Energy Supplies 2017-18 (Source: Pakistan Energy Yearbook)

Although the government of Pakistan has devised multiple policies in the past and now in the process of promulgating new policy for exploitation of indigenous renewable energy sources, there remain challenges to overcome. The challenges faced fall into two categories gaps in policymaking and implementation of the policy. In past researchers have reviewed and evaluated different energy policies of Pakistan. Asif

Shah et al (Shah et al., 2011) did a study on renewable energy policy dilemmas in Pakistan. Which were limited only to awareness among stakeholders and lack of literacy, while policies weren't discussed critically. Another notable study is of N.H. Mirjat et al (Mirjat et al., 2017), which reviewed the policies of energy and power planning in Pakistan. Tauseef Aized et al (Aized et al., 2018) undertook a study for renewable energy policy analysis, which failed to discuss renewable energy policies. Rather forecasted energy scenarios for Pakistan's future energy mix. U. Zafar et al (Zafar et al., 2018) studied renewable energy policy 2006 for its strengths and challenges. This study intends to evaluate the policies, measure the effectiveness and impact of the policies in terms of bioenergy development in Pakistan.

In this study, the bioenergy initiatives of Pakistan are highlighted, the recent policies and upcoming policy have been discussed and compared for their effect in bioenergy development of Pakistan. Furthermore, the bioenergy policy trends in India and China are overviewed, because of the similarities in energy markets and general socio-economic circumstances. Moreover, challenges faced by policymakers and implementing agencies are identified. Finally, the study proposes policy implications and recommendations for policymakers, based on the policy evaluation and challenges present, for better utilization of bioenergy potential.

2 Methodology for policy comparison

The methodology adopted in this paper is based on a comprehensive review of energy policies of Pakistan, including both general and specific to bioenergy. A total of seven energy policies were scrutinized and compared for their effectiveness in the development of bioenergy in Pakistan. The methodology is graphically presented in Figure 3 and each step is elaborated in detail in the following sections.

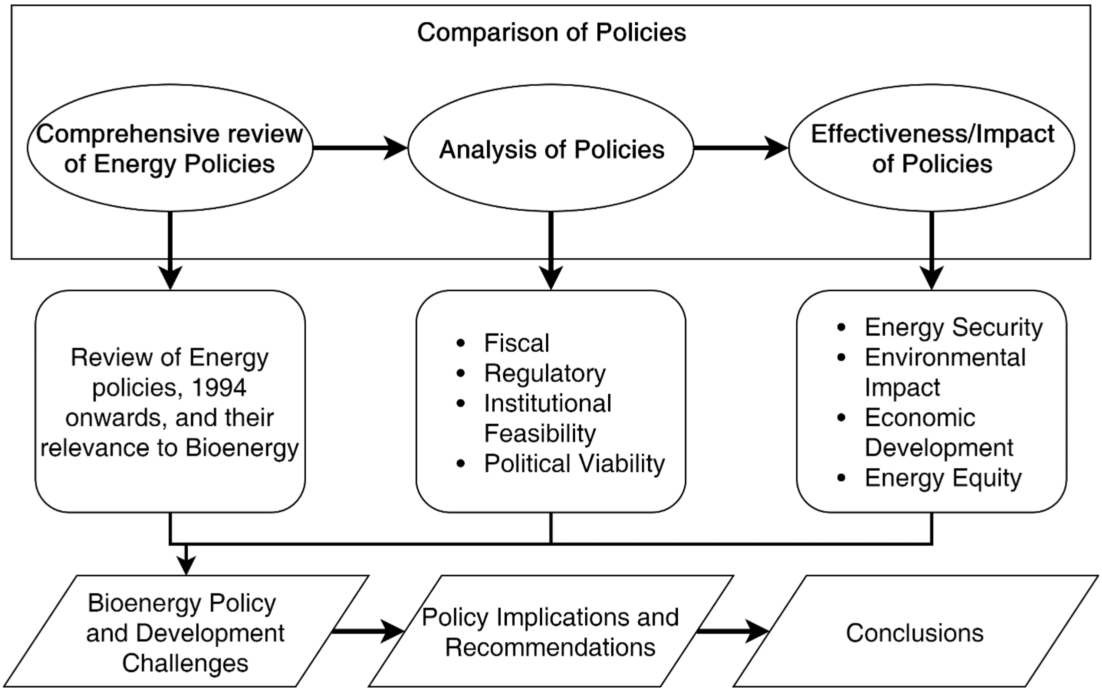


Figure 3 Methodology flowchart

2.1 Review of bioenergy dissemination initiatives in Pakistan

The literature cites different bioenergy dissemination initiatives took by different government and nongovernment agencies (Mirza et al., 2008; Zafar et al., 2018). Such initiatives were separate from energy policies for the development of bioenergy, therefore this study took a thorough review of such initiatives. The first step in this process was to search the literature for such initiatives. Along with literature, internet search engines were used to look for such initiatives. Finally, the initiatives were tabulated into two categories, government initiative and non-government initiatives for bioenergy energy dissemination in Pakistan.

2.2 A comprehensive review of recent energy policies

The second step in this study is to review the energy policies of Pakistan. The review starts with the 1994's energy policy until 2019. Original documents of the policies were gathered form sources including the Ministry of Energy, power division and other internet archives. Each policy was then perused thoroughly for their main purpose, any mention of renewable energy and for the mention of any non-conventional energy sources like energy from agricultural or municipal waste.

After studying each policy, the second step is a review of literature that analyzed or referenced to the energy policies. Different research and working papers are gathered using Google Scholar and ScienceDirect's online databases. Finally, a comprehensive review is written down using observations and inferences made by authors through the study of original policy documents and literature relevant to the energy policies of Pakistan.

2.3 Analysis and comparison of policies

The methodology used to analyze the policies was to break it down to specific policy-options that create demand for bioenergy technologies in the energy market of Pakistan. A total of 16 qualitative indicators were identified to analyze and later compare the policies. Indicators are derived from the Intergovernmental Panel on Climate Change (IPCC)'s report 'Renewable Energy Sources and Climate Change Mitigation'. The indicators have been further tailored to suit the situation of Pakistan or a likewise developing country. This study compared the policies for a number of indicators/variables fulfilled. Due to the qualitative nature of these policy options, the extent to which such a variable is fulfilled is not considered. The indicators are grouped into the following five categories, while the individual parameters are enlisted and elaborated in Table 1.

Fiscal incentives are incentives relating to finances, that have been offered around the globe for maximizing the deployment of Renewable energy. Employing such incentives can reduce upfront costs and investments related to bioenergy technology.

Public Finance entails the parameters under which show how interested the government or state institutions in providing finance to RE projects. The provision of public finance is essential for the development of bioenergy and other renewable energy technologies. The provision of public finance can trigger private investment into renewable energy technologies as well.

Regulatory incentives indicate how the government is regulating the power generation sector, either public or private, in order to increase the share of RE in power generation.

Institutional feasibility parameters are employed to evaluate the presence of institutions that regulate RE power projects, from basic stages of planning to final stages of grid connectivity and tariff regulations, and capability to impose a given policy effectively.

Political viability parameters are used to evaluate the present political situation in a given country. Furthermore, political viability also provides parameters that can analyze policy for its prior application by another country.

Table 2 Policy analysis parameters and their description

Parameter	Description	References
Fiscal Incentives		
Grants	***Grants*** are monetary assistance provided by the government for implementing new projects. Grants are one-time payments that do not have to be repaid. Grants are provided in the form of refunds after the investment has been made by the investor.	(Mitchell et al., 2011)
Tax Exemptions	***Tax reduction/ exemption*** incentives directly provide a reduction in tax, which may include sales, value-added, energy or carbon tax. Such incentives are also applied to the purchase (or production) of RE or RE technologies.	
Carbon Credit	***Carbon Credits*** are credits given to the RE producer under the Clean Development Mechanism (CDM). Which are based on reductions in carbon (Carbon dioxide) emissions as compared to a traditional power generation project like oil or coal-based.	
Energy production payments	***Energy production payments*** are direct payments, paid to the RE producer by the government per unit of renewable energy produced. Such payments are usually for a small duration of time. Which may extend up to the first year of energy production.	

Feed-in tariff (FIT)	***Feed-in tariff (FIT)*** is one of the most common fiscal incentives provided to RE producers in developed countries. FIT is a fixed price paid to the supplier (varying by technology) per unit energy delivered in the given year. FIT can be related to Energy production payment.	
Public Finance		
Investment	***Investment*** is the direct participation of public finance institutes in RE projects. Where public institutions provide finance for a share of equity in the given project/company. Such investments can be made through a venture fund model or through technology development funds.	(Mitchell et al., 2011)
Loan	***Loan*** is another type of public finance. Where eligible or economically viable RE projects are given loans for the execution of the project. Loans may not be limited to those provided by public financial institutions. They can be extended to private financial institutions as well. This may differ from general loans in terms of low-interest rates.	
Guarantee	***The guarantee*** doesn't involve direct provision of finance, it is just a role to be fulfilled by public financial institutes. To provide a guarantee a public institute provides the role of guarantor for RE companies/projects, which are seeking loans from commercial banks or other financial institutes. Guarantees are provided to people or businesses with a sound financial background or a sound business strategy.	
Regulatory incentives		

Renewable portfolio standard (RFS)	***Renewable Portfolio Standard/ Quota obligation or mandate*** are terminologies used for the same concept. To make sure there is enough green energy being produced, renewable mandates are introduced. Such mandates require existing power producers to meet a given minimum target to include RE in the energy generation portfolio.	(Mitchell et al., 2011)
Net metering (Net billing)	***Net metering (or net billing)*** is introduced to encourage small and medium-scale energy generation projects. Under net-metering, anyone with surplus power (RE in this case) is allowed a two-way flow of energy between the energy dispatch company and power producer (Captive).	
Energy banking	***Energy Banking*** is just like traditional banking, where energy is deposited and withdrawn accordingly. This regulatory tool allows a business or a person to invest in a RE plant, elsewhere than his residence. Such an investor is privileged to access energy at his choice of location in same amount as his power plant produces.	
Guaranteed power purchase	***Guaranteed power purchase*** is the guarantee provided to power producers. Guaranteed power purchase agreements are made to prioritize and ensure a buildup of the renewable energy sector. Such incentives guarantee the purchase of every unit of power produced by the RE producer.	
Institutional Feasibility		

-Potential to implement	***Potential to implement policy*** refers to the presence of institutions that deals with registration and regulation of different RE projects.	(Mitchell et al., 2011)
-Investor interest	***Investor interest*** shows the interest of the investor to invest in a given technology and political situation. Which can be easily assessed by the number of applications received.	
Political Viability		
-Existence of stakeholder support	***Existence of stakeholder support*** shows, how a stakeholder is facilitated under different situations. That may include a policy regime change.	(Mitchell et al., 2011)
-Stability of stakeholder support	***Stability of stakeholder support*** reports on the presence of long-term support for stakeholders. This parameter is employed to check whether the government targets are consistent over time. Along with incentives for stakeholders to adhere to the policy.	
Influence of stakeholder groups	***Influence of stakeholder groups*** is involved to assess policy's scope with respect to stakeholders' interests. This parameter gives an overview of stakeholder influence. Which includes ownership of key industries.	
Dependability of policy concept	***Dependability of policy concept*** means the presence of comparable policies elsewhere, and the success of such policies in countries with similar contexts.	

2.4 Evaluation of policies to gauge their effectiveness/impact

The second part in comparison of the energy policies is their effectiveness and impact on bioenergy energy development. The effectiveness of policy as defined by

Mitchell et. al (Mitchell et al., 2011) as "*The extent to which intended objectives are met, for instance, the actual increase in the amount of RE electricity generated or share of RE in total energy supply within a specified time period.*" This study not only measures the addition of modern bioenergy generation projects rather broad aspect of policy impacts into evaluation procedure. The effectiveness of policies is evaluated using four categories of parameters 1) Energy security, 2) Environmental impact, 3) Economic impact and 4) Equity impact.

A total of four parameters are identified to assess **Energy Security** through the deployment of bioenergy. Which is a concern that the consumer side is most affected by. Where energy security "*in long-term deals with timely investments to supply energy in line with economic developments and sustainable environmental needs"* (Speight, 2019).

Environmental impact is one of the major factors for considering a new powerplant (Rosen et al., 2008). A powerplant can have both negative and positive environmental impacts, here we are considering parameters to evaluate the positive environmental impacts of power generation from biomass.

Another aspect of bioenergy generation that this study evaluates is the **Economic impact**. Economic impact evaluates how much capital has been invested, savings and employment generated, either direct or indirect, as a result of bioenergy generation.

Energy equity is not given a preference when evaluating a policy for its effectiveness (Bürer and Wüstenhagen, 2009), there are different reasons for doing so. But this study also inculcates the energy equity aspect of the energy policy. Evaluation for energy equity helps to determine whether the low-income groups are reaping any benefits through bioenergy generation.

Table 3 Policy evaluation parameters and their description

Parameter	**Description**	**Reference**
Energy Security		

Installed capacity	***Installed capacity*** is the total installed electric power generation capacity in megawatts, for the given year. Installed capacity only considers power generation from bioenergy sources.	(Löschel et al., 2010)
Electricity generated	***Electricity generated*** is the total electric energy generation in the given year from biomass-based powerplants.	
Share of biopower	***Share of Biopower*** is the percentage of electric energy generated from bioenergy-powerplants with respect to total electric energy generation in the country for the given year.	
Bioenergy targets	***Bioenergy Targets*** are defined for bioenergy to be exploited in the future or in the lifespan of the policy being promulgated.	
Environmental		
Fossil fuels replaced	***Fossil fuels replaced*** is the amount of fossil fuels being replaced, if the same amount of energy is produced using petroleum products in a thermal power plant.	(Botha and Von Blottnitz, 2006)
CO_2 Reduction	***CO_2 Reduction*** is the amount of CO_2 emissions reduced because of using bioenergy sources. Though bioenergy projects emit CO_2, this CO_2 is to be recycled in the production of biomass.	
Economic		
Employment/ Jobs created	***Employment/Jobs Created*** is the number of Jobs created the bioenergy industry. This includes personnel for Supply chain, Operations, and maintenance.	(Dalton and Lewis, 2011)

Gross income	***Gross Income*** is the amount of capital generated by the bioenergy companies by selling electricity to the national grid. The study doesn't consider savings made due to captive power generation because of the limitation of data availability.	
Energy Equity		
Electricity access	***Electricity Access*** is the number of people with access to electricity out of the total population of the country.	(Sovacool, 2011), (Mitchell et al., 2011)
Electrification target	***Electrification Target*** is the target set by the policy for electrification of non-electrified areas across the country.	
Access to clean cooking	***Access to Clean Cooking*** is the percentage of the population with Access to Clean fuels for cooking like natural gas or liquid petroleum gas.	
Affordability	***Affordability*** represents the amount of household income spent on fuel and electricity. Fuel, in this case, represents fuel for cooking and heating only, it doesn't account fuel for transport.	

3 Results and discussion

3.1 Review of bioenergy dissemination initiatives in Pakistan

Literature review provides no initiatives took until the advent of the 1970s (Mirza et al., 2008). Due to rising oil prices of that decade, the government of Pakistan started a campaign for indigenous energy solutions. Tables 2 and 3 enlists the details of the initiatives took by public and private organizations for the development of bioenergy in Pakistan.

Table 4 Government sector bioenergy initiatives

Year	Project Name	Project Objectives	Results	References
1974-1987	Biogas technology dissemination program	1: 100 demonstration plants to be installed, funded by DGNRER. 2: 2000 plants to be installed on a cost-sharing basis. 3: 2000 plants to be financed by the consumer.	A total of 4137 biogas plants were installed across Pakistan.	(Mittal, 2007) (Mirza et al., 2008)
1976	Propagation of biogas technology–1	assess the feasibility of Chinese fixed dome biogas plant in Pakistan	21 Chinese fixed dome biogas plants were installed	[Experience, PCRET] (Ghafoor et al., 2016)
1979	Propagation of biogas technology–2	Reengineering and modification of Moveable gasholder biogas plant, to be manufactured easily in Pakistan.	10 demonstrations plants were set up in areas of Azad Kashmir. 100 biogas plants were installed across Pakistan	(Ghafoor et al., 2016)
2002	PC-1 by PCRET	Installation of biogas plants (1200 in total)	1600 biogas plants by the end of the project i.e. June 2006	(Kamran, 2018). (Mirza et al., 2008)

2007	PSDP financed project	Installation of biogas plants across Pakistan	A total of 2513 biogas plants were installed in the period starting from 2007 to 2012	(Mirza et al., 2008) (PCRET, n.d.)
2012	PCRET 2012 project	Installation of 50000 biogas plants by 2020	2500 biogas plants were installed by 2012	(Uddin et al., 2016) (Raheem et al., 2016)
2013	Adaptation of Biogas Technology to Mitigate Energy Crises	Dissemination of biogas technology among rural areas of Punjab	750 biogas plants of 15 m^3 and 1200 floating-drum type biogas plants were installed across Punjab	(Ghafoor et al., 2016) (Field Director General Agriculture, 2014).

Table 5 Private sector bioenergy initiatives

Year	Project Name	Project Objectives	Results	References
2007	FIDA 2007 project	Installation of four different size pilot plants in DI-Khan	Installed four different size pilot plants in DI-Khan, benefiting twenty-two households of 162 people	(Raheem et al., 2016).

2009	FIDA 2009 Project	Installation of biogas plants in DI-Khan, sponsored by Australian Agency for international development	Seven biogas plants were installed in DI-Khan	(Foundation for Integrated Development Action, n.d.).
2009	RSPN 2012 project	Installation of biogas plants on a cost-sharing basis	Installed a total of 70 biogas plants across Pakistan on a subsidized cost of Rs 7500/plant	(Amjid et al., 2011)
2009	Horizon-3	Capacity-building among dairy workers and stakeholders, sponsored by Pakistan Dairy development center (PDDC)	Firstly 450 biogas plants were installed in July 2009. Another 106 plants were installed by PDDC.	(Yasar et al., 2017)
2012	Alternative Rural Energy Through Community Led Biogas	Commissioning of biogas plants in DI-Khan	Commissioned 175 biogas plants initially and another 657 biogas plants with the collaboration of different international NGOs from 2012 to 2015	(Foundation for Integrated Development Action, n.d.).
2014	Pakistan domestic biogas program	Biogas plant installation across 12 central districts of Punjab province.	a total of 5360 biogas plants were installed.	(RSPN, 2014).

3.2 A Comprehensive review of energy policies

To understand the policy scenario of Pakistan, one must delve into the historical developments in the field of energy policy. Although the first renewable energy policy was promulgated in 2006, this study also looks at some of the previous energy policies and their relevance to Bioenergy energy development in Pakistan.

3.2.1 Pre-2006 energy policies and their relevance to bioenergy

3.2.1.1 Power Policy, 1994

This policy was driven by the power crisis of the early 1990s (Mirjat et al., 2017). The policy was meant to attract independent power producers, thus it was named as 'Policy framework and package of incentives for private sector power generation projects in Pakistan'.

This policy provided the freedom to choose between fuel type and technology. Though Bioenergy from biomass is not referred directly, there is a mention of renewable energy. The clause goes like this "*Investors may also propose projects based on hydro, or other renewable and/or non-conventional sources of energy such as solar, wind, geothermal, etc.*"

The policy didn't attract any investor in the bioenergy sector until the next policy was promulgated. Reasons for lack of investor interest included: less lucrative opportunities in bioenergy compared to oil-powered powerplants, as oil is easy to transport and store (Mirjat et al., 2017). Secondly, the policy didn't make any rules for bioenergy or renewable energy standards for power producers.

3.2.1.2 Power Policy, 1998

The power policy of 1998 focused on creating a competitive power generation market through different means (Mirjat et al., 2017). Whereas power generation from renewable energy sources was exempted from solicited biddings. Another reference to renewables not explicitly but implicitly in sub-section '*Thermal projects based on fuels other than indigenous coal*'. Such projects were asked to provide a request for proposal (RFP), enlisting parameters like delivery point/region for delivery of power and net capacity, minimum annual plant factor, availability of the power plant. While fuel availability and arrangements were the responsibility of the bidder. The price for fuel was to be provided by the bidder, which will determine the tariff for power generated.

Another reference is made in the last section of the policy document, which refers to small power plants (including cogeneration units) of less than 20MW capacity based on renewable sources. Such powerplants were given exemption from solicited proposals and competitive exemption. While tariffs to be set as average levelized tariff, based on the last twelve months. While such plants were restricted to keep capacity increase within 5% annually, to ensure a competitive solicitation in tariff determination.

A provision for powerplants intending to provide power to off-grid places was made in the policy. Such power producers were allowed deviations from the given policy. At the same time, NEPRA was to establish separate procedures for attracting private investment and setting tariffs for such powerplants.

3.2.1.3 Policy for Power generation, 2002

With the change in political regime in 1999, the new government felt the need of new and comprehensive energy policy. Thus, the policy for power generation was promulgated in 2002. For the first time there in the history of power policies of Pakistan, there is a direct reference to indigenous renewable energy exploitation. The second objective of the policy states "*To encourage and ensure exploitation of indigenous resources, which include renewable energy resources, human resources, the participation of local engineering and manufacturing capabilities*". While at another point the policy refers to the Government of Pakistan's intention to initiate feasibility studies for exploiting indigenous renewable resources. The power policy of 2002 provides incentives for the import of equipment for renewable energy projects. Such companies were exempt from income tax (which includes turnover rate tax and with-holding tax on imports).

Renewable energy projects were classified under Raw sites. Such projects were required to submit proposals to provincial governments in case of a plant size less than 50MW. Whereas for plant sized above 50MW were to submit proposals to PPIB (Private power infrastructure board). The maximum time from submission of proposals to the provision of a Letter of support (LOS) was 465 days, without including the feasibility study period.

While other requirements (including fuel choice, price, availability) for projects using fuel other than oil or coal were same as that of the power policy of 1998, discussed above.

The power policy of 2002 medium-term plan forecasted of including 500MW power from renewables in the next 15 years i.e. up to 2017.

3.2.2 Post-2006 energy policies and their relevance to bioenergy

3.2.2.1 Renewable Energy Policy, 2006

For the first time, the Government of Pakistan developed a comprehensive policy for the development of renewable energy in Pakistan. But this policy failed in catering to the needs of stakeholders concerned with bioenergy.

In the introduction, it is stated that "*Additional policy guidelines shall be issued in the future concerning biomass conversion and other RE technologies, as well as for non-power RE applications, as the sector grows, and technology advances take place*."

The scope of policy categorically states that RE technologies other than Small hydro, Solar (PV + Thermal) and wind are not in the domain of this policy. The statement goes as follow "*Other RE power generation technologies—such as those based on municipal waste and landfill methane recovery, anaerobic or pyrolytic biomass gasification, cofiring or cogeneration utilizing agricultural crop residues, biofuels, wave, tidal, geothermal energy, and fuel cells—are also relevant to current and future renewable energy use in Pakistan. However, these are not dealt with in this document.*"

3.2.2.2 PPIB, National policy for power co-generation by sugar industry, 2008

This policy came two years after the first Renewable energy policy was first promulgated. But this policy depends on fiscal and legal regimes of Power Policy of 2002. Tariff determination is done through the procedure discussed in the Power policy of 2002 by NEPRA. Co-generation policy allowed sugar mill owners to have power-producing plants that can be run as either in Captive or IPP mode as well. Another provision also allowed the sugar industry to use bagasse as fuel during crushing season and coal (local or imported) during the off-season period. Here crushing season refers to sugarcane crushing/harvesting season i.e. November to February and off-season as March to October months.

Another important provision from power policy 2002 was the imposition of fixed customs duty at 5%, on machinery imported for such projects. Another clause mentions "*indigenization to be maximized in accordance to government policy"* but doesn't mention how this will be achieved.

3.2.2.3 Frame Work for Bagasse Power Co-Generation, 2013

Framework for Power co-generation was formally approved as an addition to the RE policy of 2006 by ECC (Economic Coordination Committee) of the Cabinet in 2013. As RE policy was silent regarding Bioenergy projects, this time Bioenergy projects utilizing Bagasse, biomass, and waste were added to the scope of the RE policy 2006. This meant that all the fiscal, institutional and regulatory regimes of the 2006 policy will be applicable to Bioenergy projects, whereas power policy of 2002 was the basic regulatory model for 2008's Cogeneration policy. ECC also extended the policy regime for RE policy 2006 by another five years (AEDB, 2013).

The addition of biomass to the RE policy of 2006 was a positive step took by ECC. The inclusion led the bioenergy producers, sugar-mill owners currently, to access the incentives provided to other RE technologies. Which included Carbon credits, Energy banking and guaranteed power purchase by central power purchasing authority (CPPA).

Other major features of the policy included: Facilitation of PPIB in setting up of the co-generation power plants, using high-pressure boilers i.e. a minimum of 60bars. Co-generation plants will be able to access the financial incentives of Power policy 2002. All eligible companies were exempted from the prequalification process. They were to be issued a letter of support by PPIB after tariff has been determined by NEPRA. A major change was from earlier polices was that power producer was bound to dispatch hourly declared available capacity during the crushing season.

3.2.2.4 Alternative and Renewable energy (ARE) policy 2019

ARE policy though not promulgated officially, is in the review phase. The draft of the policy has been shared among stakeholders in academia and policy think tanks. The draft of the ARE policy shows some dramatic changes from the earlier policies. The new policy has broadened its scope, the flexibility of implementation, introduced competitive procurement of energy, emphasis on off-grid solutions and rural energy services. The policy sets a bold target of achieving 20 percent of the energy mix from renewables by 2025 and 30 percent by 2030. Keeping the timeframe in focus, achieving 20 percent energy from renewables by 2025 seems impractical.

This time bioenergy has been given the same focus as that of wind and solar. The scope now includes energy from biomass (this time extended from bagasse to other agricultural residues and wastes), Biogas and energy from waste (including municipal and industrial waste, sewage and refused derived fuels).

ARE policy is continuing most of the incentives provided under the RE policy of 2006. Incentives like tax exemptions and custom duty exemptions remain there. Regulatory tools like net metering, energy wheeling, carbon credits, and upfront tariffs are also part of the policy. While, Upfront tariffs are up to NEPRA to decide, depending on the nature of the project. Another addition to this policy is International Competitive Bidding (ICB). ICB will consider the energy source that provides the least cost. This may put bioenergy projects at disadvantage compared to conventional fuels, because of existing infrastructure and economies of scale.

Though the objectives include rural energy services and to encourage the private sector, Fiscal incentives remain out of the scope of the new policy. There are no provisions made for public loans, guarantees and investment in bioenergy or other renewable energy projects.

3.3 Policy analysis and comparison

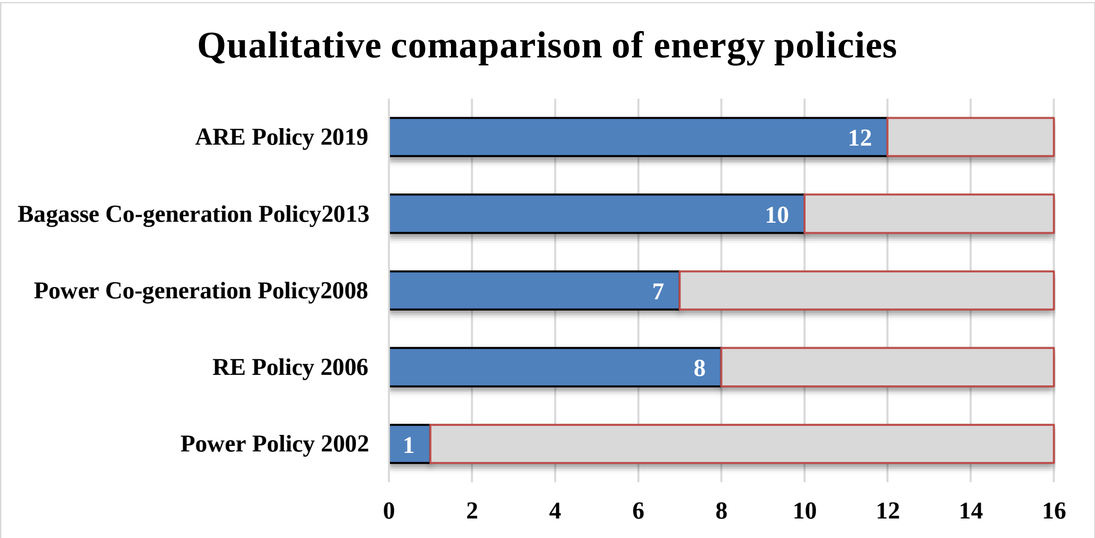


Figure 4 Qualitative comparison of energy policies

A total of 16 qualitative indicators are used to compare the policies, which are further grouped into five categories. The indicators or variables used are qualitative in nature, the policies cannot be compared on a quantitative basis. Therefore, this study compared the policies for a number of indicators/variables fulfilled, the extent to which such a variable is fulfilled is not considered.

When compared based on qualitative indicators ARE policy 2019, if implemented, came at the top, fulfilling 12 out of 16 indicators in different capacities. The following chart (Figure 4) compares the policies based on qualitative indicators fulfilled.

3.3.1 Fiscal Incentives

After close perusal of the policies for fiscal incentives, the following inferences are made: 1) None of the RE policies provide a grant for bioenergy or other renewable energy projects. 2)RE policy of 2006, provided tax incentives for RE power generation, but it didn't include bioenergy energy projects at that time. Whereas, Bagasse Co-generation policy of 2008 gave a 5% fixed import/customs duty on import of machinery required for the cogeneration plants. The 5% duty was continued under Framework for bagasse power cogeneration. Which was later changed, as Framework for bagasse power cogeneration was added to RE policy 2006 as an addendum. Which meant, all the tax incentives of 2006 will be available for bagasse power cogeneration projects and other bioenergy projects like biomass and municipal waste. 3)Carbon credits were introduced in RE Policy 2006. Which were not applicable to bioenergy projects, until 2013. After ECC's decision bioenergy projects can apply for Carbon credits as well. None of the polices have provided such incentives for RE producers. 4) As the new policy is promulgated, there will be some sort of FIT available to bioenergy projects. Though named as Upfront tariff or Cost-plus tariff. Whether to give or not, this upfront tariff will be decided by NEPRA. Criteria to be eligible for the upfront tariff is for the project to be immature i.e. there are no such projects made in the past.

3.3.2 Public Finance

All five of the policies discussed here fail to provide any investment to RE producers or project. In the case of loans, again none of the policies discussed any possibility of loans from public institutions for bioenergy project development. Nor there is a provision in the policies for commercial banks to provide loans to such projects. Similarly, neither of the policies, 2006, 2008, 2013 or 2019 provide any guarantee for projects registering under such policies for power production.

3.3.3 Regulatory Incentives

For the five policies under scrutiny for regulatory incentives following inferences were made: 1) Pakistani policymakers fail to regulate the power generation sector to include RE sources into their energy mix (Zafar et al., 2018). 2) Net metering was first introduced in the RE policy of 2006 and subsequently available under other policies as well. Though captive power production was in practice earlier than 2006. 3) Energy banking was introduced in RE policy 2006. After 2013's ECC's decision, banking is now applicable to bioenergy projects as well. 4) RE Policy 2006 provided with guaranteed power purchase from RE producers. Bioenergy projects are also provided guaranteed power purchase after the promulgation of Framework for power cogeneration 2013.

3.3.4 Institutional Feasibility

Although there are multiple organizations dealing with RE projects, AEDB stands out among them. AEDB issues standard letter of intent (LOI). Afterward, the IPP must obtain a generation license and tariff is determined by NEPRA. Secondly, there has been an increased interest of investors in power generation from biomass. According to NEPRA, 27 entities, mostly related to sugar mills, have been given generation licenses by the year 2018. While another 40 have been awarded licenses for captive power generation (National Electric Power Regulatory Authority (NEPRA) Pakistan, 2017a). There remains a lack of interest in projects utilizing biomass other than bagasse.

3.3.5 Political viability

Stakeholders, especially power producers have been incentivized since the power policy of 1994. Which provides immunity to stakeholders of any changing political situation. Which is again reemphasized in RE policy 2006 and 2019. Furthermore, the RE policy of 2006 discusses the potential for energy from biomass and estimates a 700MW power from sugar mills. But fails to assess or estimate a number for the potential of bioenergy from indigenous resources. Whereas, the Government seems consistent regarding the exploitation of RE potential from bagasse cogeneration in policies of 2008 and 2013. Another factor employed in this study to compare policies for political viability is Influence of stakeholders. According to A.

Khushk et. al (Khushk et al., 2011), 70 percent of sugar mill owners have a sole proprietorship and 60 percent of owners have family members who own a sugar mill. Thus, it can be inferred that there is a strong stakeholder base, with monopolistic nature. But there is very little or no evidence of any influence in policymaking, in literature. Whereas, the dependability of the policy concept is strong for all the policies discussed. As the world's largest sugarcane producers Brazil, India, and China have been long exploiting the RE potential of sugarcane bagasse for a long time (Geller et al., 2004) (Purohit and Michaelowa, 2007) (Gopinath et al., 2018).

Comparison is made for Pakistan's energy policies for their impact on bioenergy development is summarized in Table 5.

Table 6 Comparison of energy policies for different incentives for bioenergy producers

Policy evaluation parameters	Power policy 2002	RE policy 2006	Power co-gen Policy 2008	Bagasse co-gen 2013	ARE Policy 2019
Fiscal incentives (S)					
Grants	✕	✕	✕	✕	✕
Tax reductions/ exemptions	✔	✔	✔	✔	✔
Carbon Credits	✕	✔	✕	✔	✔
Energy production payment / Feed-in tariff (FIT)	✕	✕	✕	✕	✔

Public finance (S)					
Investment / Loan	✗	✗	✗	✗	✗
Guarantee	✗	✗	✗	✗	✗
Regulatory (S)					
Renewable Portfolio Standard /Quota obligation or mandate	✗	✗	✗	✗	✗
Net metering (also net billing)	✗	✔	✔	✔	✔
Banking	✗	✔	✗	✔	✔
Guaranteed power purchase	✗	✔	✗	✔	✔
Institutional Feasibility (S)					
Potential to implement policy	✗	✔	✔	✔	✔
Investor interest	✗	✗	✔	✔	✔
Political viability (S - R)					
Existence of stakeholder support	✗	✔	✔	✔	✔
Stability of stakeholder support	✗	✗	✔	✔	✔
Influence of stakeholder groups	✗	✗	✗	✗	✔
Dependability of policy concept	✗	✔	✔	✔	✔

R - Indicators effecting/relating Power Receiver

S - Indicators effecting/relating Power Supplier

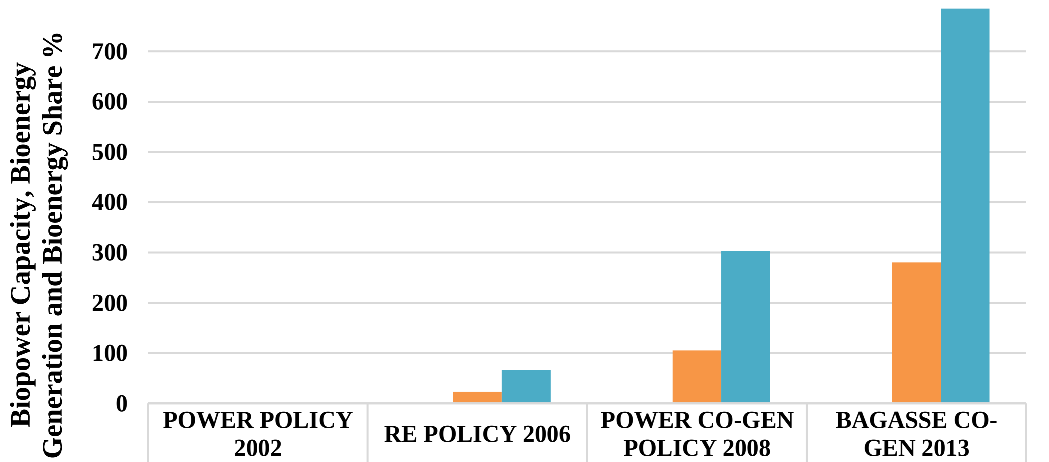
✔ Discussed ✗ Not Discussed

3.4 Policy evaluation to gauge their effectiveness/impact

A total of 10 quantitative indicators/variables are used to gauge and compare the policies for their effectiveness, which are discussed in Section 2.4. The comparison considered policies promulgated during the period of 2002-2013. All such policies have reached their lifespan. While ARE policy 2019 has been kept out, as it is in the phase of promulgation and its impact on bioenergy is a matter of future consideration. When compared based on the 10 quantitative variables, the latest policy i.e. bagasse cogeneration policy of 2013 had the highest numbers in all categories.

3.4.1 Comparison of policies for energy security

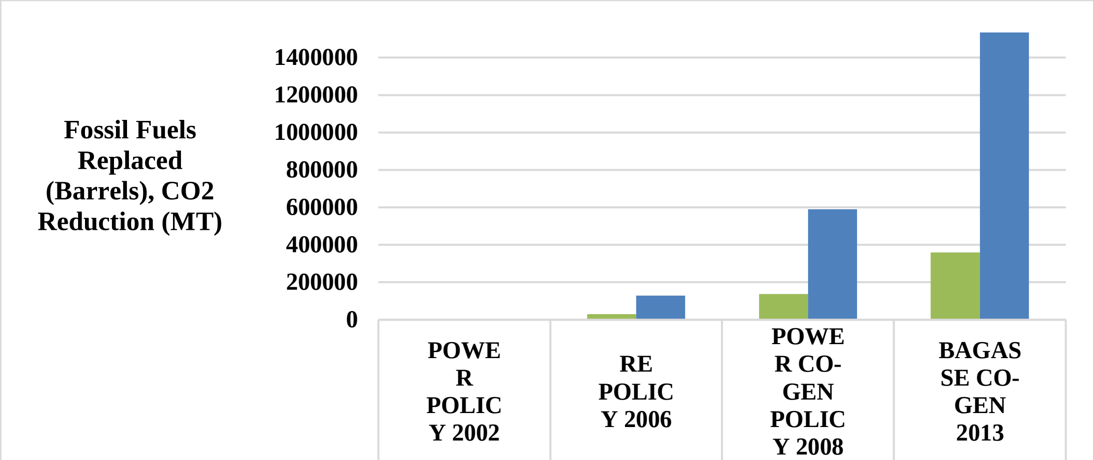
As evident from the figures for comparison Figure 5-8, it seems like there has been much increase in bioenergy generation over the years. But this increase is in bagasse powered energy generation by different sugar mills in the county. Which was a result of the promulgation of the recent two policies, i.e. Power co-generation policy 2008 and Bagasse co-generation policy 2013. There remains a large potential only in sugar mills to exploit. To put in perspective, the energy generated from bagasse powered plants was 784 GWh against a maximum potential of 2984 GWh (Arshad and Ahmed, 2016). Figure 5 represents the change in bioenergy generation over the life span of different policy regimes.



	POWER POLICY 2002	RE POLICY 2006	POWER CO-GEN POLICY 2008	BAGASSE CO-GEN 2013
Percent	0	0.06	0.3	0.65
MW	0	23	105	280
GWh	0	66.24	302.4	785

Figure 5 Comparison of policies for energy security

3.4.2 Comparison of polices for their environmental impact



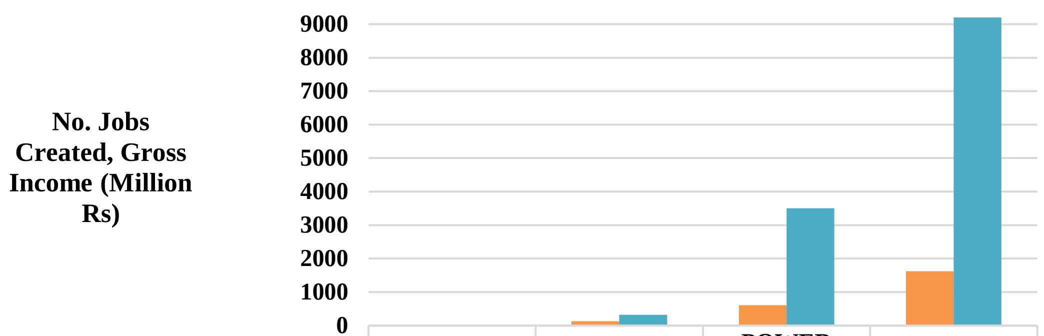
	POWER POLICY 2002	RE POLICY 2006	POWER CO-GEN POLICY 2008	BAGASSE CO-GEN 2013
CO2 reduction (Metric Tons)	0	30,272	138,196	358,745
Fossil Fuels Replaced (Petroleum Barrels)	0	129,400	590,740	1,533,503

Figure 6 Comparison of polices for their environmental impact

The second category of parameters used to evaluate policies in this study is the environmental impact. As discussed in Section 2.4, the two parameters are the replacement of traditional fossil fuels and the reduction in CO_2 emissions as a result of bioenergy generation. A nominal value of 511.9KWh/Barrel of Petroleum is used to calculate fossil fuels replaced Based on U.S EIA data for 2017. Whereas for CO_2 Reduction, though bioenergy projects emit CO_2, this study considers a hundred percent recycling of CO_2 in the production of biomass. The calculations are based on U.S EIA data for 2017, which is one pound of CO2 generated for each Kilowatt-hour of energy generated (1lbs/KWh or 0.457kg/KWh). The result for both the parameters is positive as shown in Figure 6.

3.4.3 Comparison of polices for their economic impact

The third category of parameters to evaluate the policies under discussion are economic in nature. As the presence of a strong economic aspect is necessary to attract and engage private entities to invest in bioenergy projects (Schmidt et al., 2013). The two parameters used are employment generation and income generated in the production of bioenergy. This study used the figure cited by Dalton and Lewis in their study (Dalton and Lewis, 2011) i.e. 5.8 jobs (3.5 Direct jobs and 2.3 Operation and maintenance) per MW of Bioenergy installation. Whereas, for gross income, this study doesn’t consider savings made due to captive power generation because of the limitation of data availability. Gross income has been calculated using the tariff determined by NEPRA for the given year. Gross income maxed at Rupees 9.2 billion for the year 2017. Figure 7 represents the economic impact of the last four energy policies.



	POWER POLICY 2002	RE POLICY 2006	POWER CO-GEN POLICY 2008	BAGASSE CO-GEN 2013
No. of Jobs Created	0	133	609	1624
Income Generated (Million Rs)	0	320	3500	9200

Figure 7 Comparison of polices for their economic impact

3.4.4 Comparison of policies for energy equity

A total of four parameters are engaged to evaluate energy equity. Though energy equity being a broader concept and dependent on other policies apart from the energy policy of a country. Energy policies can be effective in bringing underprivileged into energy access networks through an emphasis on off-grid bioenergy projects (Islam et al., 2018).

Data for electricity access has been cited from sources like IEA and World bank. Both of the sources remained disparate in their records. Therefore, for ease and relevance to the organization, data provided by IEA has been used in this study. Which stood at 73.6% for the year 2016. As for the electrification target, the study found none of the policies being discussed set a target for electrification. Which may be due to limitations of the scope of the policy. Whereas, Access to clean cooking stood at 44% of the population for the year 2017 (World Bank, n.d.). And according to the Pakistan Bureau of Statistics, the amount of household income spent on energy bills remained constant around 7% of total household income. Figure 8 is a graphical representation of comparison for energy equity.

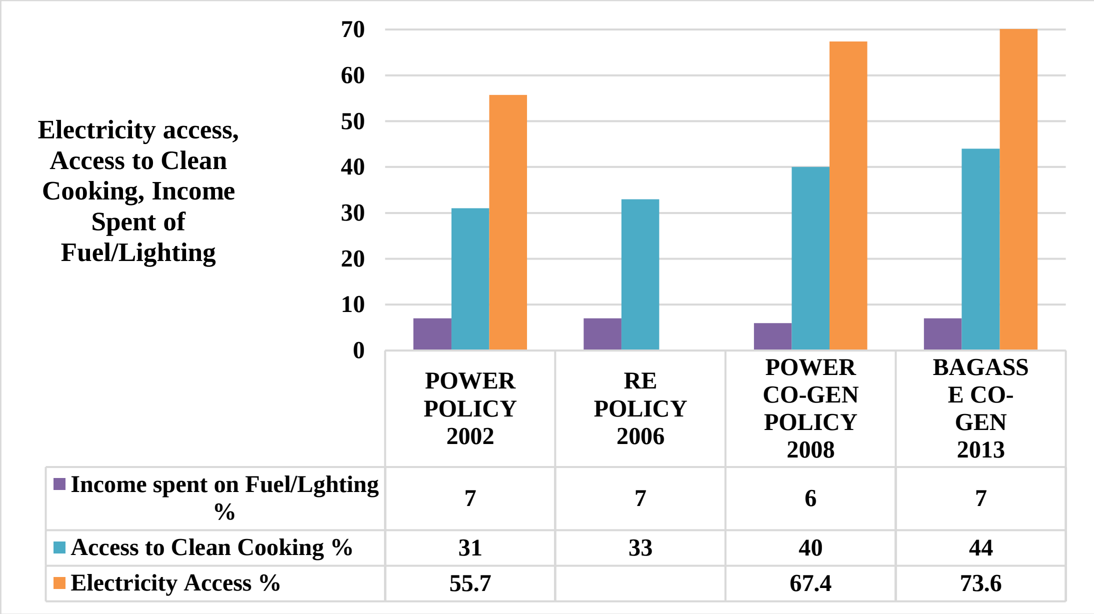


Figure 8 Comparison of polices for energy equity

3.5 Current trends in Policymaking in neighboring countries

Two of the neighboring countries, China and India, have been selected for this study. This section of the study reports some of the major policies in neighboring countries, for the sake of inspirational purposes for the policymakers. Most of the policy instruments can be replicated by policymakers in Pakistan with changes to fit the country's situation.

3.5.1 China

China is one of the leading bioenergy generating country in the world. Share of bioenergy rose from mere 3,136 Megawatts in 2008 to 16,250 Megawatts in 2016, which accounted for 1 percent of total power generation capacity of 1,625 Gigawatts (International Energy Agency, 2017a). When compared to Pakistan, the total electricity generation capacity of Pakistan in 2018 was 33,554 Megawatts (Hydrocarbon Development Institute of Pakistan, 2018). Growth in the bioenergy sector is because of China's intention to diversify its energy mix and actions taken under different Five-Year Plans. A major precedent was set after 2006's Renewable energy law, which was the major catalyst for the inclusion of modern bioenergy in the energy mix of China. According to Zhao Xingang (Xingang et al., 2013), the Chinese government is planning to add another 30 Gigawatts of bioenergy generation capacity by 2020. The boom in bioenergy can also be related to development in the technological and manufacturing base of China in the last two decades.

Along with national bioenergy development programs, Chinese provinces are working to increase the share of bioenergy. Every province has a dedicated institute for the development of bioenergy conversion technologies. Such technologies are transferred to industry via technology transfer contracts (Gan and Yu, 2008).

The policy situation is also very feasible for investors to invest in bioenergy generation plants. All the bioenergy projects are supported via different policies in different stages of industry development. For projects in the conception phase, different fiscal incentives are provided. Which includes infrastructure loans at discounted rates and establishment of a fund for financing such projects. While ongoing bioenergy projects are being provided with fiscal subsidies for operations, maintenance, and grid-connections (Kahrl et al., 2013). Bioenergy generation enterprises are given special tax exemptions. Such companies are given tax exemptions for the first three years of operations. While those bioenergy plants which utilize municipal solid waste are given exemption in value-added taxes. After 1978 the Chinese government has invested large amounts of funds in research and development (R&D) of bioenergy conversion technologies. Under the 9th Five-year plan, the Chinese ministry of science and technology spent $9.3 million in R&D activities for renewable energy development. By 2010 under the 11th five-year plan, the Chinese government spent a total of $77 million in bioenergy R&D (Xingang et al., 2013).

Keeping in the view the progress China has made in bioenergy generation Pakistan can learn and replicate most of the policies adopted by China. Pakistan needs to add bioenergy into China Pakistan Economic Corridor (CPEC) portfolio. The Pakistani government also needs technology transfer for bioenergy conversion technologies which China has expertise in.

3.5.2 India

India has made significant additions to renewable energy power generation over the last two decades. India stands third (IRENA 2018) in the list of largest renewable energy markets (first being the USA and second being China). Bioenergy is one of the significant contributors among other renewable energy sources in India. Currently, India has a capacity of 4831.33 Megawatts of grid-interactive biopower, which accounts for 11 percent of total renewable energy generation capacity (total being 42844.39 Megawatts). Off-grid biopower generation totals 994 Megawatts, which includes biomass cogeneration and energy from waste. Thus, the total amount of power being generated from biomass in India adds up-to 5940 Megawatts. Meanwhile, the government of India is planning to achieve a target of 10 Gigawatts of biopower by 2022 (Sinha et al., 2019).

India has a dedicated ministry for renewables called the Ministry of new and renewable energy (MNRE). MNRE deals with the research and development of renewable energy technologies in India. Another state institution that works for the dissemination of renewable energy in India is the Indian renewable energy development agency (IREDA). Which works under the umbrella of MNRE.

In India, bioenergy generation is facilitated through different policy mechanisms. Which includes tax incentives, subsidies, and grants for projects working towards bioenergy generation. Under the 12^{th} Five-year plan (2012-2017) Government of India apportioned Rupees 460 million for biomass gasifier scheme (Kumar et al., 2015). Some of the objectives of the Biomass gasifier scheme included: 1) Off-grid power generation program for rural areas based on Biomass gasifiers. 2) Promotion of biomass powered powerplants with more than a megawatt capacity. 3) Provisions to be made for awareness and training programs on biomass gasifiers.

Financial support and Subsidies are an important part of Indian bioenergy policy. Bioenergy projects are financed through different programs. One of them being *Removal of Barriers to Biomass Power Generation in India.* Under this program financing of up-to Rupees 15 million per Megawatt is offered to power producers using producer gas with a minimum capacity of 1 Megawatt. The program also offers finance of Rupees 3 Million for infrastructure development (Kumar et al., 2015).

Along with financial support, subsidies are provided by MNRE through Central Financial Assistance (CFA) to bioenergy projects. Along with subsidies, bioenergy projects are provided with includes tax exemptions and relaxation in custom duties (Kumar et al., 2015).

Another major policy being exercised in India is of biofuels blending mandates. The earliest of the policies is the Power alcohol act of 1948. Other major policies for biofuels include the National Biofuel Mission (NBM) of 2003, National policy on biofuels 2009, which proposed a mandate of 20% biofuel blending by 2017 (Sinha et al., 2019).

Other policy instruments used in India for the promotion of bioenergy technologies include: Feed-in tariffs, renewable purchase obligation for utilities and renewable energy certificate (REC) trading through clean development mechanism (CDM). As Pakistan and India share a common history and similar markets, Pakistan can easily replicate most of the policies being enacted in India for the promotion of bioenergy.

3.6 Bioenergy policy and development challenges

This section aims to identify the current lying challenges that policymakers face in developing the policy and implementing institutions face while the execution of the policy. The challenges have been identified through the study of literature for the current situation of Pakistan.

3.6.1 Ad-hoc policymaking

Policies are created to cater to the needs of a particular time, though such policies may be applicable to other situations as well. The problem is the lack of long-term planning and policymaking towards a sustainable energy mix and maximum utilization of indigenous resources (Mirza et al., 2007)(Mirza et al., 2009)(Mirjat et al., 2017). Such ad-hoc policymaking in Pakistan deterred the sustainable development of bioenergy dissemination.

3.6.2 Competitiveness with conventional fuels/energy sources

Pakistan’s energy sector relies mostly on conventional fossil fuels for power generation. According to Pakistan energy yearbook, fossil fuel consumption in thermal power generation totaled 19 MTOE, which accounts for 68 percent of total generation (Hydrocarbon Development Institute of Pakistan, 2018). The power generation from fossil fuels and their imports are highly subsidized (Zafar et al., 2018), which makes the bioenergy generation less lucrative.

Other factors that affect the dissemination of bioenergy is the seasonality of biomass availability (Rentizelas et al., 2009). As Pakistan has low forest cover (Butt et al., 2013), the viable option of biomass is the crop residue. While the crop residue is available only in the harvesting season, which makes energy generation from such sources less attractive for investors.

3.6.3 Limited interoperability of state institutions

Matters related to energy generation are dealt with by following state institutions in Pakistan, Ministry of Energy (Power and Petroleum Division), Alternative energy development board (AEDB), PPIB and PCRET. Though each institute has its own responsibilities, there remains a poor culture of information sharing between such institutions. According to Usman Zafar et. al (Zafar et al., 2018), there is a lack of cooperation between such institutes and ministries. Another glaring example of lack of cooperation is between the Hydrocarbon development institute of Pakistan (HDIP) and PCRET. HDIP, which is working on different blends of biofuels and gasoline (Mirza et al., 2008), could work with PCRET in developing such biofuels from indigenous biomass resources. While lack of cooperation could lead to duplication of such projects, and loss of time and public resources.

There are other state institutions that are not directly related to energy generation or energy policymaking but are linked indirectly. Two of such institutions are the Ministry of climate change and the Ministry of environment. Both organizations advocate for alternative and renewable energy sources, which the policymakers of energy must keep in mind while making energy policies. Synergy between such institutions is necessary for the creation of a comprehensive and sustainable energy policy.

3.6.4 Absence of developed infrastructure

Pakistan’s power distribution is network is centralized. Electrification rates remained too low for rural areas, where access to the centralized grid is not possible. While most RETs are decentralized in nature, they can cater to such off-grid communities. But the absence of a developed infrastructure impedes the exploitation of bioenergy sources in rural areas, where bioenergy resources are abundant. Infrastructure refers to the established power generation machinery industry. Thus, Pakistan has to import power generation machinery, which increases initial costs. In the long run, such infrastructure requires the support market as well. Which includes after-sale services and support technologies. Lack of such a support market leads to further cost additions.

The presence of a strong industry base for power generation machinery and support market can lessen the costs related to RET installation and post-installation costs, leading to growth in the bioenergy market.

3.6.5 Deficiency of skilled workforce

Along with a strong infrastructure, the renewable energy industry requires a skilled workforce for installation, commissioning, operations, and maintenance of the power generation plants. Which is another area where Pakistan lags. Presently, there is a dearth of skilled workforce and technical institutes to produce such people.

The lack of such a workforce can be a result of low demand and low activity in this sector. As the private sector never ventures into businesses where returns on incomes are low, therefore government must step in to fill this vacuum. By creating a pool of skilled workforce, through trainings within the country and abroad, this lacking can be fulfilled. Meanwhile, support for the personnel wishing to enter this business through entrepreneurial models must be supported by the government through business incubators and venture funding.

3.6.6 Policy Implementation

Another challenge for bioenergy policy is the implementation of the policy made. In a country like Pakistan where the policies are politically driven, and institutions are deeply politicized (Ali and Beg, 2007), the implementation of such a policy can cause political discontent. Along with politicization, the poor professional culture among government employees (Yousaf et al., 2016) also leads to poor policy implementation.

Though there can’t be quick fixes for such problems. This challenge can be overcome over time by making provisions for checks and balances for employees of government institutions. Another measure can be taken to create a panel to deal with grievances and discrepancies faced by clients.

3.7 Policy Implications and Recommendations

3.7.1 Regulatory incentives

Policies relevant to bioenergy generation lack regulatory incentives to attract investors. The Feed-in tariff, which is one of the most common regulatory incentives provided in most countries, should be offered to independent power producers using biomass feedstock for energy generation.

Secondly, biomass cogeneration should be encouraged through policy initiatives. As Pakistan’s electricity sector depends on fossil fuels for two-thirds of its generation. Such powerplants can use biomass feedstock along with conventional fuels in their combustors with simple modifications. Policymakers in Pakistan must add a renewable portfolio standard or quota obligation for current power producers. The mandate should start with a modest quota of renewables in total generation with subsequent increments over the years.

3.7.2 Financial incentives

As discussed in Section 3.3, the current and previous policies of Pakistan lacked financial incentives to attract investors. Thornley and cooper (Thornley and Cooper, 2008) concluded in their study that investment subsidies have been effective in developing bioenergy in Germany, U.K, Sweden, and Italy. Fiscal incentives being provided in India and China can be replicated for Pakistan's case. Grants should be provided to bioenergy projects through public finance. Especially to small and medium scale bioenergy producers catering to off-grid and rural areas. A mechanism should be formulated to provide loans for power projects using biomass feedstock. Provisions should be made for disbursement of Loans through public financial institutes and commercial banks.

Most of the equipment for power generation is being imported, as Pakistan lacks a developed power machinery industry. Taxes and duties imposed (currently 5% customs duty) on such imports must be relieved. The government of Pakistan provides some incentive in sales tax for renewable power projects under the RE policy of 2006. This tax relaxation must be extended to other types of taxes and new entrants in RE markets must be given tax holidays for 3 to 5 years of the initial investment.

3.7.3 Institutional process

Currently, power projects less than 50 Megawatts are processed by AEDB and for projects more than 50 Megawatt they are dealt with by PPIB. The project needs initial accreditations from AEDB or PPIB, then they are eligible for tariff determination by NEPRA. This process lengthy and requires multiple legal formalities to be achieved. Therefore, to attract more investors, both national and foreign, this process must be eased. Though AEDB and PPIB are categorized as one window operation facilities, there needs further improvement in the efficiency of the process. A helpline or a helpdesk must also be created to attract and facilitate potential investors/clients.

Secondly, institutional harmony must be created between institutions like AEDB, PPIB, NEPRA, and other power utilities. Information sharing between the above institutions can ease the process of registering new power projects.

3.7.4 Stakeholder confidence

One of the essential parts of policymaking is the involvement and confidence of stakeholders in policymaking (Mitchell et al., 2011). While the policies are meant to facilitate the stakeholders and citizens, their input towards policymaking can be meaningful. Trends as early as a decade ago, have emerged where stakeholders' participation is ensured in policymaking (Leary, 2004). Renee Irvin and John Stansbury in their study (Irvin and Stansbury, n.d.) stated following advantages of stakeholder participation in policymaking: A better appreciation of larger community among the public, a way to tackle deterioration in public trust and a tool for transformative social change.

Pakistan needs to work on this factor. Policymaking must include across the board members both from the public and private sectors as well. Policymakers can take advantage of already present private bodies like Pakistan Sugar Mills Association, Livestock Farmers & Breeders Association, and other relevant bodies.

Another key stakeholder is academia. Pakistan currently has a large number of academics and think tanks working in areas of policymaking. Such professionals and their expertise can be exploited in policymaking. Therefore, policy input should be taken from academia and think tanks working in the country as well.

3.7.5 Long term planning and diversification

As pointed out by Fahd Ali and Fatima Beg (Ali and Beg, 2007) previous power policies were politically driven and certain people took benefit from it. Secondly, the Bagasse cogeneration policies were enacted out of pressure from increasing power demand and decreasing production. This process of ad-hoc policy planning needs to end. And a comprehensive policy should be made from long-term policy planning using different quantitative and qualitative techniques. Energy modeling tools like MARKAL-TIMES, MESSAGE or EnergyPlan must be used in forecasting and energy planning for a sustainable and resilient power policy. This can be done through a successful collaboration between legislators, stakeholders, academia and think tanks working in the country. As highlighted by Weishu et al. (Liu et al., 2014), a stronger relationship between academic research and the promotion of bioenergy. Currently, different institutions are working in this sector independently. Academic researchers are working on their own or with fundings from Higher Education Commission (HEC). While state institutions like PCRET, HDIP, PSO and other relevant organizations are working independently. While large projects and policies are studied by international consultants for their feasibility. This must be stopped, and a nexus of academia and state institutions must be made for collaborations in different projects and studies both for feasibility and implementation. Thus, saving both hours of work and money.

Secondly, the bagasse power generation has received much attention over the years. In fact, specific policies were promulgated for bagasse powered energy generation. Policymakers need to expand the bioenergy base to include other sources. Which may include other major crop residues, both harvesting, and processing residues, biofuels from different sources and energy from waste.

3.7.6 Capacity building

Pakistan lacks a strong industrial base for the production of power machinery. Along with lack of industry, there is a dearth of skilled workforce for installation/commissioning, operations, and maintenance of such power generation machinery.

Pakistan desperately needs an investment in capacity building of already existing industry, so that they can enhance their capacity to make power generation machinery and support items for the need of the local market. This can be done through collaboration with China and other countries with a sophisticated industrial base for technology transfer and capacity building of enterprises currently working in Pakistan. To create a strong workforce the policy must be enacted for the development of technology parks and allocation of funds for research and development in the field of bioenergy technology (Maes and Passel, 2019).

3.7.7 Awareness programs

Campaigns regarding bioenergy have been limited in history. As discussed in section 4, there has been an initiative to disseminate bioenergy technologies through pilot projects. But still, communities are reluctant to adopt such technologies on their own. Therefore, there needs to be more of such initiatives to make bioenergy technologies attractive.

Biomass feedstock which comprises mostly of crop residues is found in rural areas of Pakistan. Most of the residue is sold to brick kilns, where access is limited crop residue is burned directly (Mir et al., 2017). This is where policy needs to be enacted for awareness among farmers and brick kiln users. People involved in such practices are small scale farmers and brick kiln owners, with little or no education. Therefore, provisions must be made for awareness programs among this community. Such people must be trained to use modern biomass conversion techniques.

Another area where people need to be made aware of is the economics of bioenergy technologies. There remains misconception regarding high investment risks, uncertainty about renewable energy resources, relatively high capital cost among the general population. These misconceptions can be removed through seminars and media campaigns. Institutes like Chambers of Commerce and Industry can play a positive role. As each district in Pakistan has its own Chamber of Commerce and Industry, campaigns made on such platforms can reach a large number of small and medium scale businesses.

4 Conclusions and Policy Implications

The primary was to analyze and evaluate the energy policies of Pakistan. Additionally, the study presented the history of initiatives took for the development of bioenergy in Pakistan. Most of the projects built under these initiatives are out of service or totally abandoned. Reasons being lack of support from the government and skilled workforce to operate and maintain them. While policies were promulgated at different times across the history of the country. Despite such initiatives and policies, the share of bioenergy in the total energy mix remains dismally low. For the year 2017, the energy generated from bagasse powered plants was 784 GWh against a maximum potential of 2984 GWh (Arshad and Ahmed, 2016). This study analyzed and evaluated the last four energy policies (one being general power policy, the second renewable energy policy and the other two for bagasse cogeneration) and the upcoming Alternate and renewable energy policy. The different aspects of the Policies were compared, including regulatory, fiscal, political and institutional feasibility, and effectiveness. Effectiveness was compared in terms of energy security, environmental concerns, economic aspects, and equity. The analysis put the upcoming policy i.e. Alternate and Renewable energy policy remained at front and the Framework for Power cogeneration among the policies evaluated. Still, most of the bioenergy potential in Pakistan remains unexploited. The challenges to policymaking were mostly of endogenous nature, which can be overcome through policy measures. Two of the major bioenergy markets of the world, both being the neighboring countries, China and India, were reviewed for the policies and initiatives taken for the development of bioenergy. Most of the initiatives and policies were found to be easy to replicate in Pakistan's situation. It is further concluded that 1) bioenergy policy needs to diversify its scope from bagasse to other sources like crop residues and municipal waste, 2) policymakers need to provide incentives for private entities to invest in bioenergy sector, 3) policy needs to ensure provisions for awareness and capacity building among stakeholders, 4)set targets and plan accordingly to exploit the underutilized bioenergy resources in the country.

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6 Appendix

The following tables (A1-A4) include the complete statistics, notes, and references for the parameters used in Section 3.4. Most of the statistics have been reported from different research papers, annual reports by government organizations like the Ministry of Power, NEPRA, AEDB, and other energy agencies like IEA, US-EIA, IRENA, World Bank, and Asian development bank.

Table A1 Energy security through bioenergy

Policy evaluation parameters	**Power policy 2002**	**RE policy 2006**	**Power co-gen policy 2008**	**Bagasse co-gen 2013**	**Current status – 2017**
Energy security (R^1)					

Installed capacity (MW)	0 MW	0 MW	23 MW	105 MW	280 MW
Electricity generated (GWh)	0 GWh	0 GWh	66.24 GWh[2]	302.4 GWh[2]	785 GWh
Share of Biopower	0	0	0.06%	0.3%	0.65%
Bioenergy Targets	No targets Defined	No Targets Defined	No Targets Defined	No Targets Defined	No Targets Defined
References	(Government of Pakistan, 2003)	(Government of Pakistan, 2007)	(National Electric Power Regulatory Authority (NEPRA) Pakistan, 2008)	(National Electric Power Regulatory Authority (NEPRA) Pakistan, 2013a) (Hassan, 2016)	(National Electric Power Regulatory Authority (NEPRA) Pakistan, 2017a)

[1] R- Indicators effecting/relating Power Receiver/Customer

[2] Calculated, assuming 24hours operation for 4 months (Nov-Feb - Sugarcane harvesting season)

Table A2 Environmental impact of bioenergy generation

Policy evaluation parameters	Power policy 2002	RE policy 2006	Power co-gen policy 2008	Bagasse co-gen 2013	Current status - 2017
Environmental impact (R[1])					
Fossil fuels replaced [a]	0	0	129,400 Petroleum Barrels	590,740 Petroleum Barrels	1,533,503 Petroleum Barrels
CO_2 Reduction [b]	0	0	30,272 Metric Tons of CO_2	138,196 Metric Tons of CO_2	358,745 Metric Tons of CO_2

[1] R- Indicators effecting/relating Power Receiver/Customer

[a] Based on U.S EIA data for 2017, i.e. 511.9KWh/Barrel of Petroleum (U.S EIA, 2019a)

[b] Based on U.S EIA data for 2017, i.e. 1lbs/KWh or 0.457kg/KWh (U.S EIA, 2019b)

Table A3 Economic impact of bioenergy generation

Policy evaluation parameters	Power policy 2002	RE policy 2006	Power co-gen Policy 2008	Bagasse co-gen 2013	Current status - 2017
Economic impact (R[1])					
Employment/ Jobs Created [a]	0	0	133	609	1624
Gross Income [b]	0	0	Rs 323 Mill. [c]	Rs 3.55 Billion	Rs 9.2 Billion

[1] R- Indicators effecting/relating Power Receiver/Customer

[a] Based on data provided by Dalton and Lewis (Dalton and Lewis, 2011) i.e. 5.8 jobs (3.5 Direct jobs and 2.3 Operation and maintenance) per MW of Bioenergy installation

[b] Based on the average tariff determined by NEPRA for the given year (Rs 11.7396 per KWh for the year 2013 and 2017) (National Electric Power Regulatory Authority (NEPRA) Pakistan, 2013b)(National Electric Power Regulatory Authority (NEPRA) Pakistan, 2017b)

[c] Based on Tariff of Rs 4.88 kWh set for Almoiz Industries by NEPRA in 2008 (Arshad and Ahmed, 2016)

Table A4 Energy equity through bioenergy generation

Policy indicators	**Power policy 2002**	**RE policy 2006**	**Power co-gen Policy 2008**	**Bagasse co-gen 2013**	**Current status - 2017**
Energy equity (R[1])					
Electricity Access	52.9% (2000)	55.7% (2005)	No Data	67.4% (2010)	73.6% (2016)[a]
Electrification Target	70% Rural	No Data	No Data	No Data	No Data
Access to Clean Cooking	25%	31%	33%	40%	44%
Affordability [b]	7%	7%	7%	6%	7% (2015-16)
References	(Government of Pakistan	(World Bank, n.d.),	(World Bank, n.d.), (Pakistan	(International Energy	(World Bank, n.d.),

	, 2003; International Energy Agency, 2017b; Pakistan Bureau of Statistics, 2002; World Bank, n.d.)	(International Energy Agency, 2017b), (Pakistan Bureau of Statistics, 2006)	Bureau of Statistics, 2008)	Agency, 2017b)	(International Energy Agency, 2017b), (Pakistan Bureau of Statistics, 2016)

[1] R- Indicators effecting/relating Power Receiver/Customer

[a] For the same year i.e. 2016, World Bank reported an electrification rate of 99% (World Bank, n.d.)

[b] Average amount, as a percentage, of income spent on fuel and lighting. Source: Pakistan Bureau of Statistics

7 References

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