KADIR HAS UNIVERSITY

GRADUATE SCHOOL OF SCIENCE AND ENGINEERING

AN EVALUATION OF ENERGY AND ELECTRICITY IN PAKISTAN

GRADUATE THESIS

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February, 2016

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M.S

2016

AN EVALUATION OF ENERGY AND ELECTRICITY IN PAKISTAN

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Submitted to the Graduate School of Science and Engineering
in partial fulfillment of the requirements for the degree of
Master of Science
in
INDUSTRIAL ENGINEERING

KADIR HAS UNIVERSITY
February, 2016

AN EVALUATION OF ENERGY AND ELECTRICITY IN PAKISTAN

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ABSTRACT

EVALUATION OF ENERGY AND ELECTRICITY IN PAKISTAN

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February, 2016

Pakistan is a developing country and it can only move forward once the energy sector is secure and self sufficient. Right from the beginning, the country has constantly faced energy shortages in all sectors due to incompetent policies and governence. This study frames the analysis of the current energy situation, with main focus on electricity. All the factors which are hampering the growth of the energy sector are identified and potential solutions are discussed. Matching the electricity supply and demand is the ultimate goal, therefore a forecast analysis (multiple regression model) based on seasonal variation in temperature is performed in order to predict the future electric consumption and help authorities take necessary actions for fulfilment. Finally, a comprehensive detail is provided on the causes and problems of the energy crisis, and potential solutions and reforms are provided.

Keywords: Pakistan Energy, Electricity, Energy Policy, Multiple Regression Model, Demand Forecast.

Acknowledgements

First of all I will thank the Almighty for helping me come this far and paving the way ahead of me.

I would like to express my utmost gratitude and love towards my family, especially my parents Khurram Humaiyun and Saadiah Humaiyun, who have stood by me in difficult times and helped me for whatever I have right now. I also appreciate their patience for all the period I have been away from home.

I express my gratitude and great respect to my advisor Prof. Dr. Volkan Ş Ediger for the useful comments, remarks and engagement through the learning process of this master thesis. Furthermore, I would like to thank my co-advisor Assoc. Prof. Ahmet Yücekaya, whose vast knowledge helped me finish the thesis. I am grateful to both my advisors for their help and encouragement.

I would like to thank my dear Irsa Chaudhry, the southpaw, through whom I learned the fact that flames of hope can never burn brightest without utmost despair. I would also thank my great friend, Mr. Ain Ali for his precious support and presence throughout this difficult time, may you be at the highest of highs.

Last but not the least, a very special thanks to my family in Turkey, Serkan ışık and Örge Tokdil along with their parents, for showing such love and hospitality. My heart is always open to you.

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List of Abbreviations

ADB	Asian Development Bank
AEAI	Advanced Engineering Association International
AEDB	Alternate Energy Development Board
BTPL	Bahria Town Pvt Ltd. Co.
CHASNUPP	Chashma Nuclear Power Plant
CNG	Compressed Natural Gas
CPPA	Central Power Purchasing Authority
DISCOs	Distribution Companies
FESCO	Faisalabad Electric Supply Co.
GENCOs	Generation Companies
GEPCO	Gujranwala Electric Supply Co.
GOP	Government of Pakistan
GWh	Gigawatt-hour
HESCO	Hyderabad Electric Supply Co.
IESCO	Islamabad Electric Supply Co.
IMF	International Monitory Funds
KANUPP	Karachi Nuclear Power Plant
KESC	Karachi Electric Supply Co.
LESCO	Lahore Electric Supply Co.
MEPCO	Multan Electric Supply Co.
MW	Megawatt
NTDC	National Transmission and Dispatch Company
PAEC	Pakistan Atomic Energy Commission
PEPCO	Pakistan Electric and Power Co.
PESCO	Peshawar Electric Supply Co.
PPIB	Private Power Infrastructure Board
QESCO	Quetta Electric Supply Co.

SEPCO	Sukkur Electric Supply Co.
TESCO	Tribal Areas Electric Supply Co.
WAPDA	Water and Power Development Authority

Chapter 1

Introduction

1.1 Statement

As the world stepped into the age of industrial revolution, it has turned into a power house with rapid industrialization and automation. This transformation started with first phase of the industrial revolution in late 18th century with the advent of the steam engine which targeted a chain reaction of industrial processes. Gradually, people started to look for a more convenient form of energy which could be easily transformed from one form to the other and transmitted. Hence the second phase of industrial revolution saw the discovery of electricity as a form of energy (Britannica 2015). With the works of scientists like Tesla and Edison, electricity became the main source of energy for all sectors. Consequently, after 1970s the age of computers emerged, followed by robotics. Now, almost everything we own or use requires energy to run, and most important form is the electric energy. Electricity is one of the most vital type of final energies for socioeconomic development of the society. It nurtures the world as we know and is the very basic fragment of a developed world. It is the input power for machineries in factories and industries, for household gadgets, for lighting our cities and running the vehicles. The ever growing global competitiveness in science and technology requires any country to possess a sound energy profile. Therefore, for developing countries like Pakistan, the top priority should be to gain a sustainable electricity sector in order to promote advancement. Without it, the whole industrial sector will shut down, resulting in a dead trade and economy. There will be no metropolitan activities, no research and development, no educational activities and hence leading the country towards a 'stone age' like era.

When Pakistan gained independence in 1947, the energy infrastructure was almost non-existent. There was only a small hydro power availability, and no energy was being utilized through fossil fuels (Ullah 2013). As time passed, the government realized the importance of a developed energy sector, and hence Water and Power Development

Authority (WAPDA) was created in 1959 to handle the growing energy needs of the country. Numerous hydro projects were initiated and new oil and gas reserves were discovered. A sound infrastructure based on power generation by hydro and thermal resources was laid out and the sector continued to grow up until 1980s, after which the energy crisis started to emerge (Rauf et al. 2015). To tackle this problem, energy policies in 1985, 1994 and 1998 were developed but apparently none of them have been successful till date. Consequently, all the energy demanding sectors of Pakistan are severely suffering. There is extreme shortage of electricity resulting in lost industrial production and development, suffering commercial and domestic sectors and downfall in trade, economy and GDP. The country's economy is largely based on textile production and agriculture with exports more than 60% of the total (Kalsoom 2008). Both these sectors require an unhampered flow of electricity in order to fulfill production potential, which is obviously not present at current conditions. If the country wants to achieve any success, it needs to feed the industrial and commercial sector with sufficient power supply. In this thesis, we will study all the pros and cons of the sector, and try and identify the main problems and suggest possible solutions, keeping in view the present status of the infrastructure.

1.2 Scope and Outline of the Study

In this study, firstly I have identified the overall energy sector, mainly the primary and final energies. Then focused on the electricity sector, highlighting all the key factors included from production till consumption. Analysis based on changes in trends, historic comparison and major developments are discussed. I then provided a mathematical model to identify the future consumption of electricity in the country and compared my results with other studies for validation. Finally, keeping in view the performance inspection done in this report, I proposed possible solutions and reforms which can help the sector to reincarnate.

The thesis consists of five chapters, as listed below.

Chapter 1 provides introduction, including history and importance of energy and electricity in this era. Also provides the basic structure of this thesis and a brief detail about previous studies done on electricity sector of Pakistan.

Chapter 2 includes the overview of the energy sector of Pakistan. It provides the basic numbers concerning primary energy production, imports, exports and conversion to final energy. Consumption of final energy in the form of electricity is also discussed.

Chapter 3 is based on the electricity infrastructure of Pakistan. It gives the governing structure details, types of power plants and fuels, installed capacity, generation (including costs), transmission and distribution, electricity consumption and matching of supply and demand.

Chapter 4 contains forecasting of electricity consumption on monthly basis with seasonal variations. The method used is multiple regression model with independent variables including population, GDP, industrial production index and temperature. The results are compared with a number of other studies and reports.

Chapter 5 outlines the crisis faced by the country in terms of shortage of energy. Problems and their causes are discussed in details, and possible solutions are provided to help Pakistan pull itself out of this crisis. Finally, the conclusion based on the overall status of the energy infrastructure is provided.

1.3 Literature Review

There is an extensive literature available on the energy and electricity sector of Pakistan, ranging from detailed energy outlook to forecasting to renewable energy integration. The current crisis has led many researchers and scientists to take part in the energy battle, and try to find a final solution once and for all. Almost all of the studies are published with the energy shortages as the main issue of discussion. Some of the most recent publications on electricity sector of Pakistan are reviewed below.

Zaman et al. (2012) proposed a multivariate electricity consumption function for Pakistan with economic and population growth being the input variables. They used Wald-F statistics and concluded that population growth, foreign investment and income are positively correlated with the electric consumption but with different levels of impact (1% increase in income, international investment or population increases electricity consumption by 0.973%, 0.056% and 1.605% respectively).

Ullah (2013) explained the overall value chain of electricity infrastructure from production to consumption. The existing problems and future measures to improve the system are highlighted. Causes including governance failure, inadequate policies, and non-implementation of reforms are mentioned. Finally, the Theory of New Institutional Economics is applied for further research on the power sector.

Iqbal et al. (2013) estimated the electricity demand function for Pakistan using smooth transition autoregressive (STAR) model. This model correlates the consumption with variation of the GDP. They pointed out that continuous investment in the power sector is required to meet the increasing demand of electricity for a resultant increase in GDP. They concluded the results with analysis of using cheap resources for power generation, and the effect on pricing and tariffs.

Kessides (2013) points out the hardships that are being faced by the individuals and businesses in Pakistan due to the electricity deficits. He mentions that it is the main reason of the socio-economic failure of the country and has emerged due to institutional and governance failures. He drafted an improved potential policy in order to end this energy bankruptcy.

Ali et al. (2013) used ARIMA model to forecast the electricity consumption with varying in seasonal temperature in Pakistan until 2020. Their model displayed that with increase in temperature, the consumption will also increase and July 2020 will see the highest demand of 6785.6 GWh.

Nayyar et al.(2014) in their publication, 'Assessment of present conventional and non-conventional energy scenario of Pakistan', reviewed and assessed the demography of the country versus energy sectors, supplies, consumption, reserves, electricity generation and demand supply. They mostly concluded that conventional resources are not enough to satisfy the growing energy needs, and a well-planned renewable energy setup is required to solve the energy problem.

Satti et al. (2014) attempted to evaluate the relation between coal consumption and economic growth of Pakistan. They applied the VECM Granger causality approach and concluded that there is a bidirectional Granger Causality between the two factors.

Mahmood et al. (2014) proposed some methods in order to minimize the energy deficits. They analyzed the effects of energy imports on fulfilling the energy supply and demand gap. They discussed the proposed projects including Turkmenistan, Afghanistan, Pakistan and India (TAPI) project; Iran, Pakistan and India (IPI) gas pipelines; Liquefied Natural Gas (LNG) import from Qatar. They also proposed the development of infrastructure on basis of renewable energy.

Perwez et al. (2015) established the overview of the electricity sector of Pakistan with historical summary of supply and demand. They used a Long-range Energy Alternate Planning (LEAP) model to forecast the demand of electricity. They divided the future scenario into three parts; i) Business-as-usual, in which they assumed the future electricity sector to maintain the current growth status; ii) New Coal (NC), in which they assumed the future electricity production to be mainly based on the coal resources of Pakistan; and iii) Green Future (GF), in which the forecast with renewable energy integration in mind. They concluded with policy implications of model for future electricity generation and environmental policies.

Rauf et al. (2015) gave a comprehensive details on the energy sector of the country from establishment, history and achievements to energy reserves, electricity generation/consumption, and renewable energy potential. Finally, they pointed out the causes of the energy crisis and provided solutions.

Shaikh et al. (2015) diagnosed the overall conditions of the Pakistani electricity sector with potential and planned developments to improve the overall situation. They evaluated the implementation of the National Energy Security Plan, a government proposed plan to rejuvenate the energy infrastructure of the country, and came to the conclusion that no progress has been done in practicing this plan. Finally, they discussed the alternative energy solutions which can tackle the ongoing energy deficits.

Zakaria and Noureen (2016) in their report, 'Benchmarking and regulation of power distribution companies in Pakistan', used stochastic frontier analysis to determine the cost effectiveness and efficiency of the power distribution companies working under the government. Their model concluded that there is 72.5% average efficiency of this sector, and this further deteriorates the quality of service. Their results are compared to my own evaluation and close matching is found. The distribution network of the country is in the worst state and rapid action needs to be taken to cut down the losses incurred by public companies.

Hussain et al. (2016) applied Holt-Winter and Autoregressive Integrated Moving Average (ARIMA) models to forecast the electricity consumption sector-wise. They came to the conclusion that the gap between electricity supply and demand will steadily increase if no appropriate actions are taken. According to their results, the residential sector will eventually have the highest demand. They recommended some solutions, which can finally eradicate the gap between supply and demand.

All these studies contains the detailed information on the electricity sector of Pakistan. Almost all of them research about the energy shortages Pakistan is facing in one way or the other. According to my conclusion, if the best aspects of these studies can be collected into one box and implemented in the current energy policy of the country, they can act as *coup de grâce* to the crisis.

1.4 Materials and Methods

Most of the analysis done in this study is based on the statistics provided by the National Electric and Power Regulatory Authority (NEPRA) and the Pakistan Private Investment Board (PPIB) in the State of Industry Report 2014. The data include information about all the power plants, historic installed capacities and generation, production and consumption, etc.

Data was also collected from historic archives of plant licenses, policy reports and law papers. The main source of material and data are the government records of statistics, and also studies done on this information by various people. In addition, information was collected from a number of previous studies done by researchers residing within Pakistan as well as abroad. Facts and figures were compared and the best solution was chosen to be presented in this report. The method used for forecasting of electric consumption is explained in details in chapter 4.

Chapter 2

Overview of the Energy Sector in Pakistan

2.1 General Outlook

Pakistan is richly blessed with various forms of energy resources, the effective utilization of which can boost the country's economy. The energy setup is under direct or indirect control of the government and a number of private agencies. The end consumer include residential, industrial, commercial, transport and agriculture sectors, while the supply mix consists of oil, gas, coal, hydroelectricity and nuclear energy. When Pakistan gained independence in 1947, the energy infrastructure was almost non-existent. As time passed, the structure also developed and new gas and oil reserves were found and new projects started to emerge. Rauf et al. (2015) identifies in their study that the energy sector gained momentum after 1970s and continued to grow until 1990s, during which international investments by World Bank and other agencies were flourishing. According to them, a number of mining projects were developed and power plants were commissioned by the government, including the large hydro, thermal and nuclear setups. After 1990s, the power crisis started to emerge due to factors like political unrest, downfall of economy and terrorist threats. The sector got stagnant and no new major developments were made for resource mining and power generation projects.

In the past decade, the problems have worsened and there is an extreme shortage of available energy. It is also a bi-product of poor management, lack of operations, lack of capital, and lack of planning and solid policies. To add more, the gas reserves of the country are diminishing which is alarming due to the fact that the energy sector is most reliant on this fuel. The country has insufficient oil reserves to substitute for gas, and it is economically impossible for Pakistan to import large amounts of oil or gas in order to meet the energy demand. A massive 186 billion tons of coal reserves were recently discovered, but there is no coal based facilities present and it may take a lot of effort and time for its proper development. Due to under-funding and absence of a sound research and development sector, the renewable energy technology is not yet established in the country, while the potential for it is impressive given the geological properties.

Energy shortage is the most significant player in bringing down the economy of the country. Besides lack of availability of fuel for transportation, heating and industrial use, the electricity sector is suffering the most. Kessides (2013) mentions the amount of shortfall of electric supply to have reached value of over 5000 MW, resulting in power outages of more than 20 hours per day in some villages. The reasons, he identifies include insufficient installed capacity, circular debt, revenue inadequacy, availability and efficiency of existing power plants, power losses and expensive means of production. Besides this, there are a number of studies which identify the same basic fundamentals of the problems, and provides with feasible solutions but unfortunately no substantial developments are being followed by the government as yet and the energy problems persists and getting worse day by day. Rauf et al. (2015) points out that the country can still pull itself out of this crisis with smart future planning and implementation. All available energy resources should be fully exploited, especially indigenous and renewable ones, and conservation of energy should be practiced. It is difficult, but not impossible, to implement a coherent energy policy for a sound energy security of the country

2.2 Primary Energy Supply and Final Consumption

Pakistan is dependent on oil, natural gas, coal, hydro and nuclear for its commercial supply of energy. In 2013, the total production and consumption of primary energy was 64.59 MTOE and 40.18 MTOE respectively (although the production is larger than the consumption, the difference is due to a number of losses which will be later discussed) (NEPRA 2014). Natural gas plays the most significant role in the energy mix of Pakistan, contributing to 48% of the input. It is harvested from local fields, with Sui and Mari being the largest ones. When gas was discovered in 1950's, the reserves were thought to be virtually ever-lasting. Therefore, the energy infrastructure was molded in a way which was mainly gas dependent. It is being used for power generation, domestic heating and cooking and as vehicle fuel. Unfortunately, the accessible gas reserves are now coming to an end, and with the current consumption rate, it is prone to be finished by 2025-26 (GOP 2011). Consequently, the government has taken certain actions to slow the rapid exhaustion.

The second most important fuel in the energy mix is oil, contributing about 32% of total energy. It is both produced locally and imported. There are a number of refineries which convert the crude oil into refined products. This source is used for power generation and transportation purposes. Due to the scarce reserves of oil in the country, most of it is imported and this results in a burden on the delicate economy of the country.

Coal is a major source of energy all around the world, but in Pakistan it plays an insignificant role in the energy mix. The main consumer of coal are the industries. The hydro source is abundant, especially in the north region of Pakistan. Although it is not fully utilized, but is an important source for electricity generation. As far as nuclear energy is concerned, it is used for power generation. Although the first nuclear plant was established in 1972, there has been no substantial development in this sector since then and it contributes minute energy in the mix.

Currently, Pakistan plays no role in imports or exports of electricity. Only a small amount of electricity is imported from Iran, amounting to 74 MW, for the coastal area of Makran. It is considered to be a test project, and a foundation for upcoming potential projects planned by both governments. The project is being expanded to 100 MW for now, and later will grow up to 3000 MW (The Express Tribune 2016).

2.2.1 Resources and Reserves

Rauf et al. (2015) studied the natural resource reserves in their research and will be outlined in the following text. According to the report, Pakistan has enough resources to make its energy sector self-sufficient, and even export to neighboring countries. Figure 2.1 highlights the energy reserve utilization till year 2030.

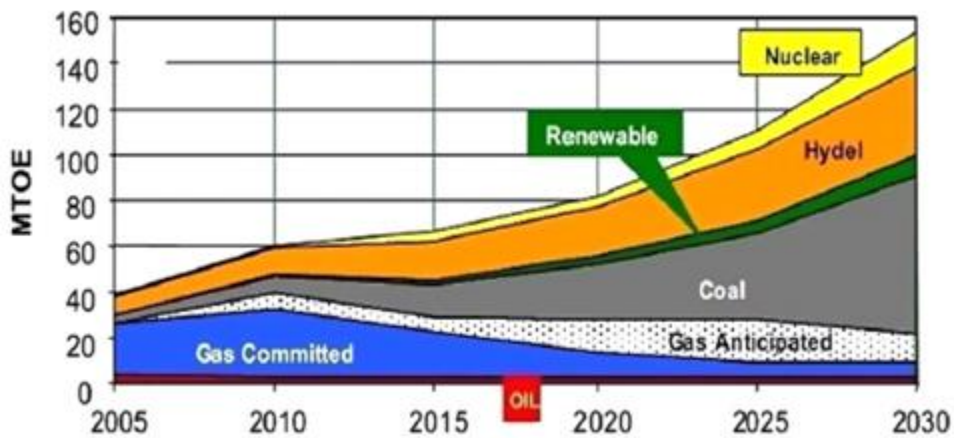

Figure 2.1 Energy reserve utilization of Pakistan till 2030 (Meyhoefer 2008)

Coal

Coal deposits in Pakistan are estimated to be 6th largest in world. Although the coal reserves were known at the time of independence, but it was not until 1980 that detailed survey was made in economic and technical grounds. Geographic location of the coal deposits are illustrated in figure 2.2. Most of the 186 billion tons of reserve is found in Thar Desert and Lakhra in Sindh province. Coal quality ranks from lignite to sub-bituminous with a comparatively lower heating value of 6223 Btu/lb to 10288 Btu/lb. This proves the fact that there is low utilization of coal as an energy source due to high processing cost of such quality. There is only one coal-fired power plant present in Pakistan, which used 104,604 tons to produce 40 GWh of electricity in 2013, while most of the coal is consumed by the cement and brick kiln industries.

Oil

According to NEPRA's State of Industry Report 2014, the recoverable reserves of crude oil in Pakistan are estimated to be 371 million barrels. In 2013, 27.84 million barrels were produced from these reserves. Figure 2.3 illustrates the oil and gas deposits, and it can be seen that most of them are present in the province of Sindh, while some can also be found in the province of KPK.

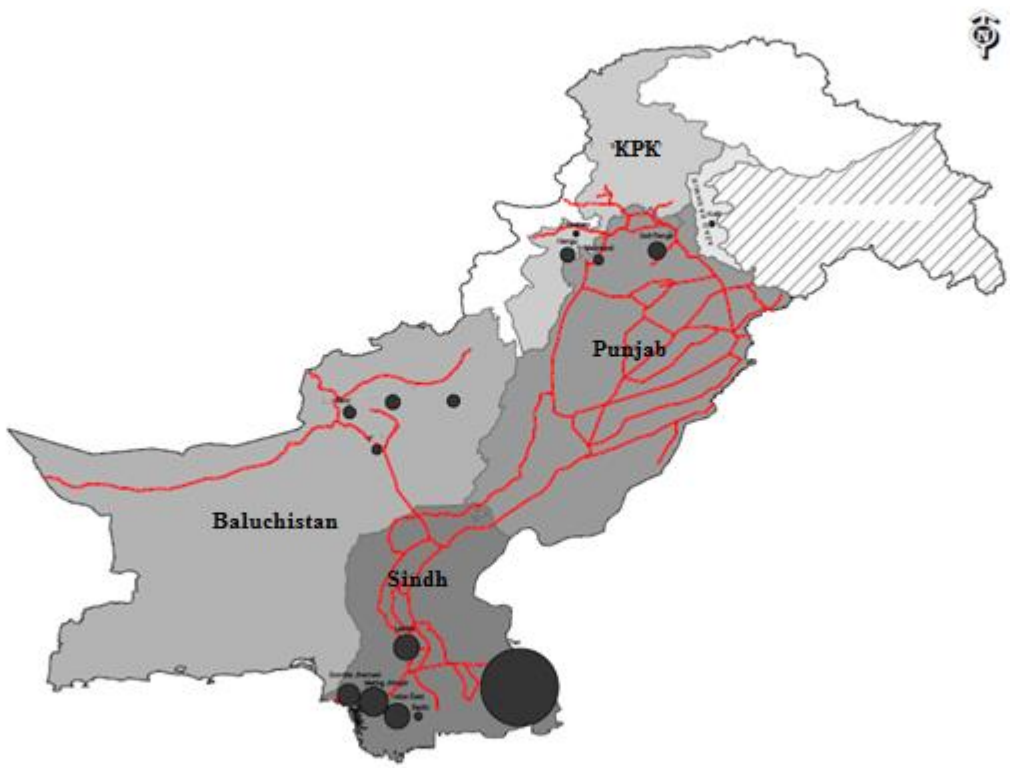

Figure 2.2 Coal reserves of Pakistan (Alhasan Systems Pvt.Ltd., 2012)

The refining capacity of the country is 18.79 million barrels/year, while 10.75 million barrels was processed in 2013. Total imports of crude oil in 2013 amounts to 7.4 million tons, costing $600 million and most of it is imported from Gulf States. The locally produced and imported crude oil is converted into furnace oil, light diesel oil, high speed diesel and motor spirit. In power generation, fuel oil and high speed diesel are used. In 2013, 7.75 million tons of these two products were used as fuel inputs in thermal plants

(NEPRA 2014). The main consumers of oil are the transport and the power sector, with a 90% share of the total consumption.

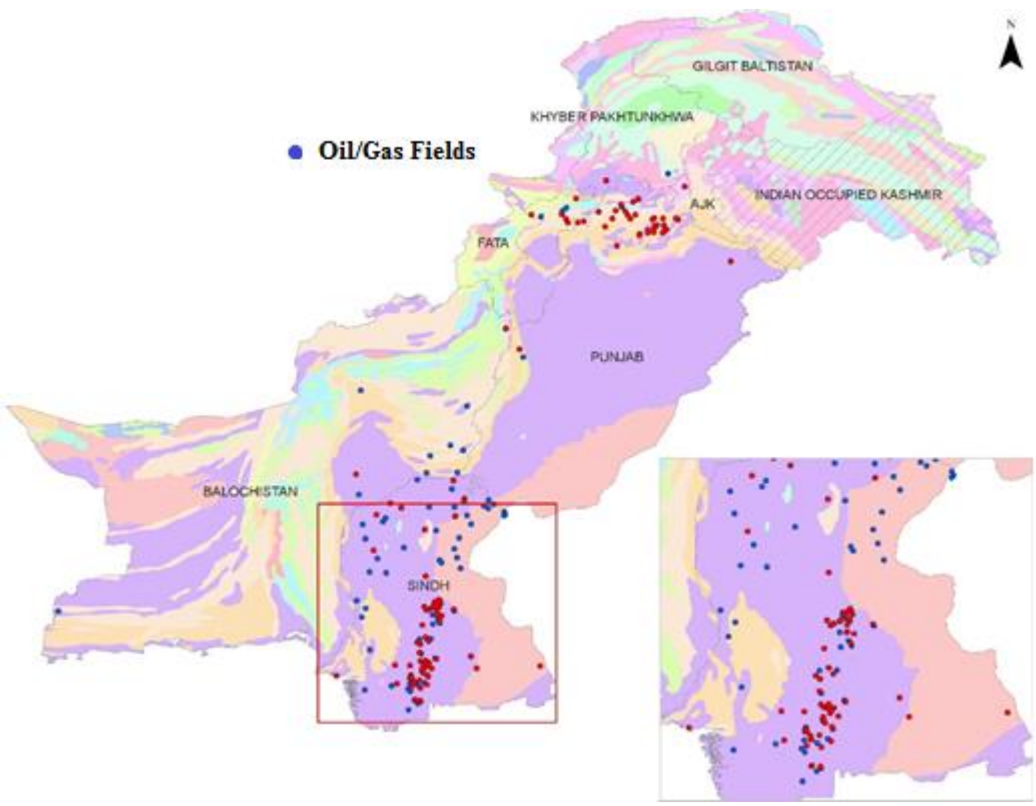

Figure 2.3 Oil and gas reserves of Pakistan (Alhasan Systems Pvt.Ltd., 2012)

Natural Gas

Extraction of gas requires a heavy investment, with cost recovery time of 10-15 years. In Pakistan, the obtainable reserves of natural gas are estimated to be 24.74 tcf. In 2013, 1,505,841 mcf was produced (equivalent to 32 MTOE). Most of the gas fields are present in the province of Sindh, as shown in figure 2.2, with Mari and Sui being the main ones. There are about 15 companies which are extracting gas from about 190 gas fields.

Hydel power

Pakistan has an ample hydel resource present in the northern areas amongst the mountainous regions. Melting of glaciers from the high peaks allows for a huge potential energy in the flowing water. In spite of this, a very low amount of this energy source is harvested for electricity generation. There are just three main hydel dams which are present in Punjab province. Hydro power is alone considered to be a sufficient source of electric generation, with 65,000 MW of identified projects and 100,000 MW potential, while only 7,117 MW is currently installed (The Express Tribune 2015).

Nuclear energy

Pakistan is among the 30 countries in the world which utilize nuclear energy. Uranium is locally harvested and imported from China. Nuclear energy is used for generation of electricity, and about 787 MW of capacity is installed in Pakistan. Although, the nuclear setup has been present for more than four decades in Pakistan, but the growth has been close to none. There are four main uranium deposit sites present in the country, with an estimated amount of 1160 tons (OECD 2010).

Renewable energy

The geological nature of Pakistan provides favorable conditions for renewable energy resources. Due to situation near the equator, there is plenty of sunshine with an estimated potential of 50,000 MW for solar power generation. The sunshine lasts about 7-8 hours per day in the provinces of Sindh and Baluchistan. Similarly, the wind potential is estimated to be 20,000 MW and the government is collaborating with a number of international companies in order to deploy wind power generation setup in the country. A number of projects are already in operation and a few major ones are pipelined and proposed. Biogas, geothermal and ocean wave energies are also abundant, but little or no work has been initiated in these fields. The government should research projects to calculate the feasibility of these renewable projects and approach investors in order grow this setup for sufficient supply of energy. Alternate Energy Development Board (AEDB) has been recently setup in order to pursue development in this sector.

2.2.2 Primary Energy Supplies

Production of primary components includes coal, crude oil, oil products, gas, nuclear and hydro. In energy budget 2013, 64.59 MTOE was the net energy supply consisting of coal, oil, gas, nuclear and hydro. Figure 2.4 illustrates the energy supplies in Pakistan. The key component in the energy mix, as mentioned earlier, is clearly natural gas with around 48% of share. It is followed by oil, with around 33% of the share. Hydro power is one of the first resources used in Pakistan for electricity generation. Although it does amount to a significant value, but if used to full potential, it can supply ample energy to the whole country alone. Coal supplies a small amount to the energy, around 6%. Nuclear energy is used for electricity generation, with around 1-2% of share in the energy mix.

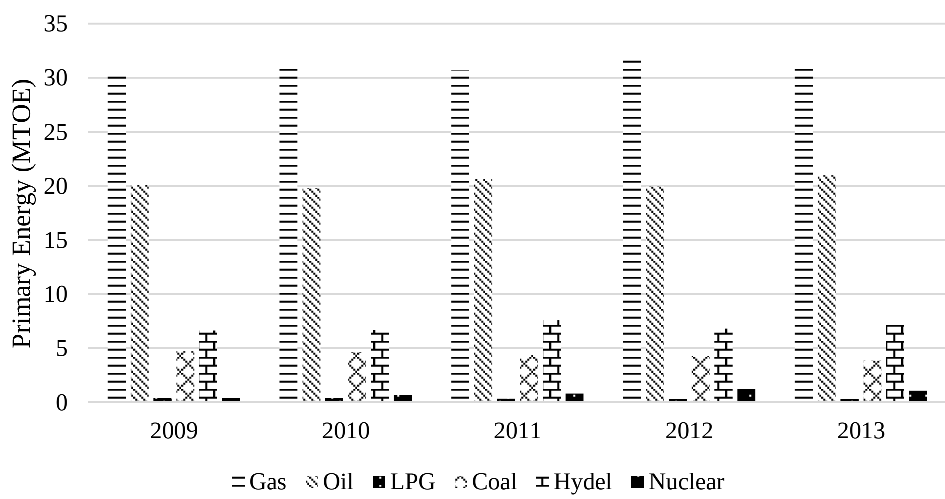

Figure 2.4 Primary energy supply by fuel type, 2009-2013

Following are the import figures for 2013:

- Coal: 2.557 MTOE (2.9% of total primary energy)
- Crude oil: 7.819 MTOE (9.1% of total primary energy
- Oil products: 11.651 MTOE (13.5% of total primary energy)
- Total imports: 22.027 MTOE (25.6% of total primary energy)

The figures show that Pakistan is not heavily reliant on imports of energy because of weak economic structure, less bilateral correspondence and extreme political corruption. This is one of the major reasons of energy shortages. As a comparison, Turkey imports more than 75% of its energy products and therefore the energy supply and demand is matched and the country faces no major power crisis.

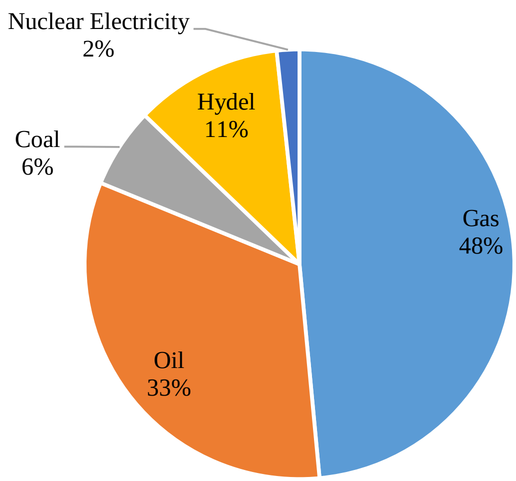

Figure 2.5 Energy mix, 2013

2.2.3 Final Energy Consumption

The main forms of final energy are gas, oil, coal, LPG and electricity. These supplies are provided to the consumer end; including industrial, transport, residential, commercial, and agricultural sectors. In 2013, 40 MTOE of final energy was consumed. Figure 2.6 shows the final energy consumption by resource type in Pakistan. The consumption of oil and gas has a slightly rising trend between the years shown in above diagram. This can be explained by the increase in electricity generation as well as industrial and domestic consumption.

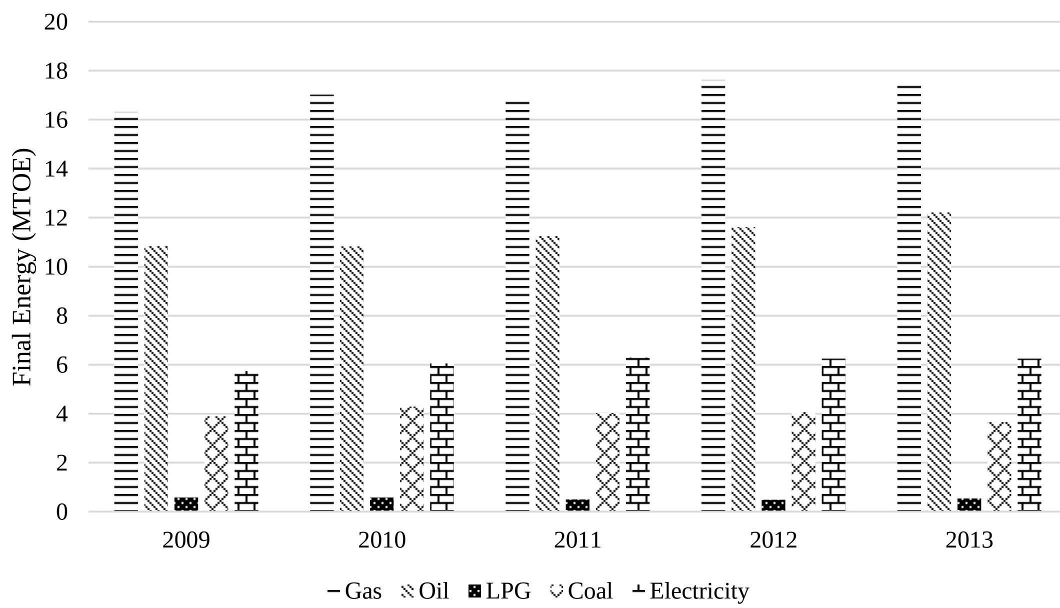

Figure 2.6 Final energy consumption by fuel type, 2009-2013

The transition of primary to final energy results in an inevitable loss in the form of heat, mechanical motion etc. Figure 2.7 shows the primary energy vs final energy, where the area in between is the loss. In 2013, 24.41 MTOE of energy accounted for wastes and losses which makes 37.7% of total energy. This energy loss can be decreased, but not fully cancelled as the laws of thermodynamics explains. The causes of the lost energy includes auxiliary consumption by plants and refineries, heat and mechanical losses, and other miscellaneous causes like theft or unaccountability.

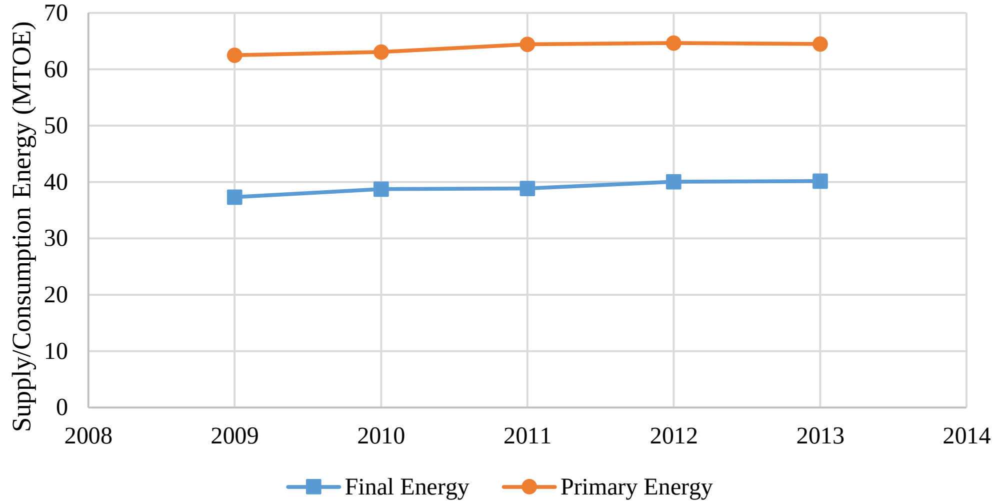

Figure 2.7 Primary supply vs Consumption of energy, 2009-2013

The heaviest consumer is the residential sector, shown in figure 2.8. Mostly, gas and electricity are the two main components in this sector. The transport sector includes oil and gas consumption. Industrial sector includes coal, oil, gas and electricity consumption. The non-energy uses are mostly for chemical productions like mobile oil etc.

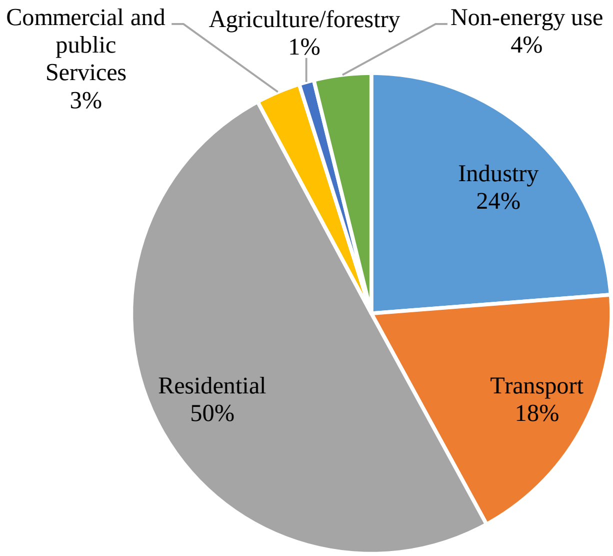

Figure 2.8 Sector-wise energy consumption, 2013

Pakistan only exports 0.8 MTOE of crude oil, which is a minute number. The overall production and consumption scenario can be explained by the energy budget, which provides the balancing of production, imports/exports and consumption. A detailed statistics of the energy budget of 2013 are given in tabular form in table A.1 in Appendix A (International Energy Agency 2014).

Chapter 3

Electricity Infrastructure of Pakistan

3.1 Overview

In 1947, the newly formed state of Pakistan inherited an intalled capacity of 60 MW of power plants for a population of 31.5 million (ICCI 2011). Figure 3.1 shows the details of the electricity system of Pakistan. Electricity sector in Pakistan consists of power plants including thermal, hydro and nuclear with a transmission and distribution system. All of the hydro plants are present in the provinces of KPK and Punjab, which is in the northern part of the country. The thermal plants are situated mostly in the main areas, including provinces of Punjab and Sindh.

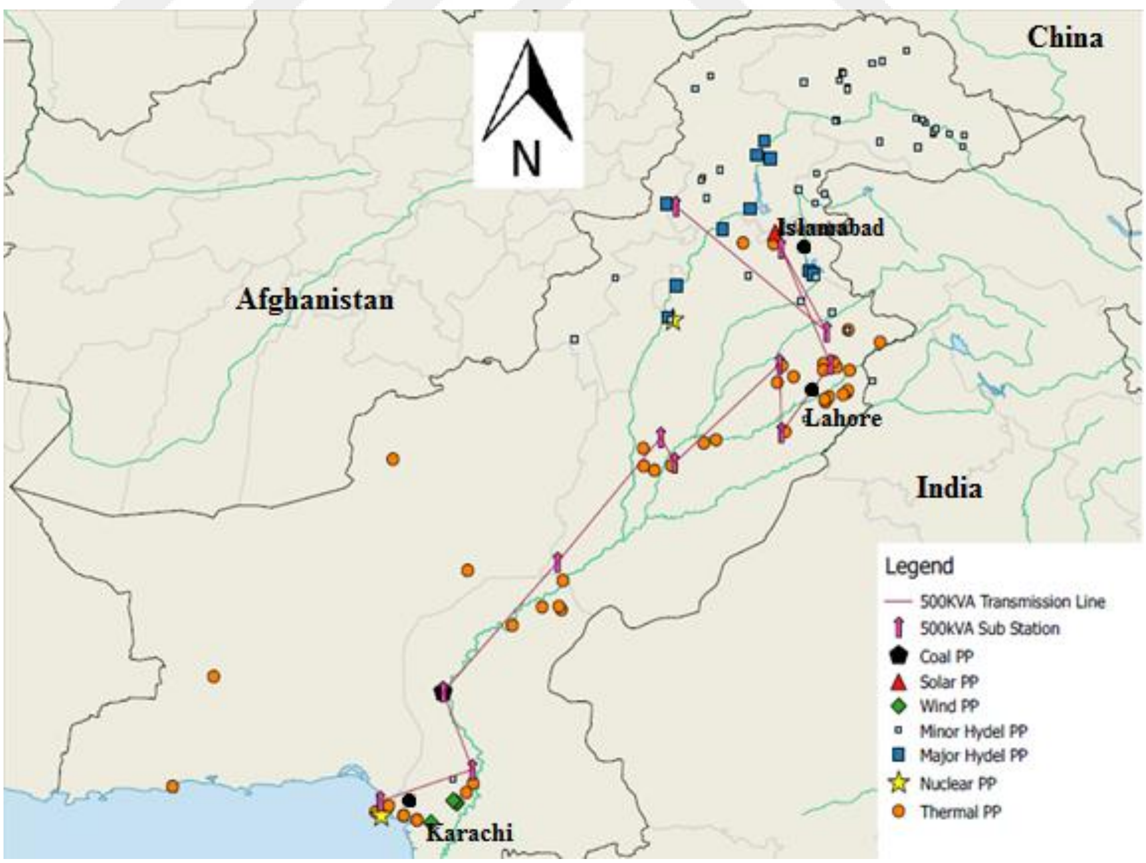

Figure 3.1 Electricity infrastructure map, 2015 (NEPRA 2014)

It can be seen in the figure that only four thermal plants are present in the province of Baluchistan (east side of the country). The main transmission line of 500 kVA runs from lower KPK, through Punjab and ends up in Sindh. Rest of the areas are served by smaller transmission network. Karachi Electric Supply Co. (KESC) and rest of Sindh is delivered with electricity from the northern Pakistan through this main transmission line. Generally, the country has a biased distribution of the electric sector components, with Punjab and Sindh being the most favored areas. The reasons for this are the population density and the presence of metropolitan cities.

The country has been facing electricity shortages right from its inception to present day. Initially, the industries were hit by the crisis, and now the whole country is suffering. The Power Policy 1994 was aimed to overcome this newly built crisis. It was identified that the demand growth has risen from 4% per annum to 7% per annum from 1990s to 2000s, but the policy failed to fulfill this demand growth in every aspect (Rauf et al. 2105). Throughout this study, factors leading to the shortages will be identified.

Change in economy and electricity generation are strongly correlated and the figure 3.2 shows that the growth rate of GDP remain low with those of power generation. Trade and economy have been severely affected by this drop in GDP and industrial output has dropped by 15-35% in recent years (Iqbal et al. 2013). Rauf et al. (2015) also identifies the importance electricity and GDP. They mention in their report that for 1% increase in GDP, an increase of 1.25% in electricity generation is required.

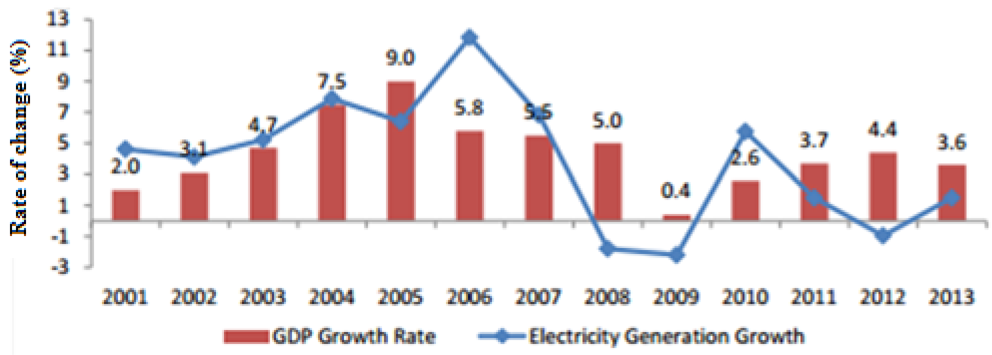

Figure 3.2 Correlation between electricity and GDP growth, 2001-2013 (Iqbal et al. 2013)

3.2 Structural Organization and Deregulation of the Electricity Sector

Timeline showing major development in the electricity structure of Pakistan is given in the figure 3.3. Before independence, Karachi was one of the main cities of India and in 1913, the government formed KESC to provide power to the city and its adjoining areas. After independence in 1947, there was no distinguished authority for regulation of the power sector. As the power needs increased, the country needed a body to administer the sector, hence Water and Power Development Authority (WAPDA) was formed in 1959 (Iqbal et al. 2013). The sector saw satisfactory performance and growth but the country started to face electricity shortages in mid 1980s

The effort to restructure Pakistan's power sector in mid 1980s was hence initiated in order to cope up with the power shortages. Incompetent governance and heavy losses within the system were becoming a hindrance to an uninterrupted supply of electricity, therefore it was realized that power capacity, generation and transmission efficiency and expansion could only be achieved by intervention of the private sector (Malik 2010). Prior to this, power generation in Pakistan was a monopoly, completely state-owned and operated (Hagler Bailly Pakistan 2003). The first private power policy was instituted in 1985, and was aimed to encourage private investors to take part in electricity generation.

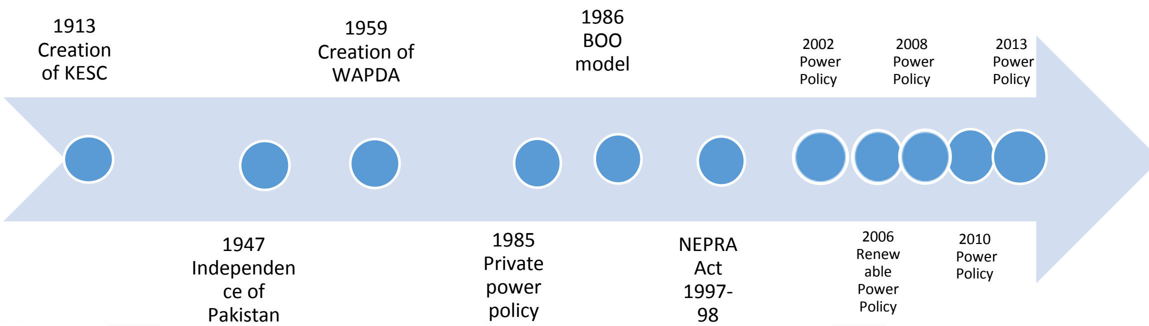

Figure 3.3 Timeline showing major developments in the electricity structure

In 1986, the government introduced BOO (Build-Own-Operate) investment model, but there was a lack of sufficient incentives to attract the private investors (Ullah 2013). At this stage, the electricity infrastructure was exclusively under the government bodies, the WAPDA and KESC. All segments of value chain were concentrated within these entities.

Later, the Asian Development Bank (ADB), International Monetary Funds (IMF) and World Bank motivated the restructuring of this system through institutional changes to improve the efficiency and the quality of the system. Consequently, major steps towards deregulation were taken in the Power Policy of 1997-98. Privatization of the structure was initiated and WAPDA was unbundled, however only generation sector was opened to market competition while transmission and distribution were separated from WAPDA into public companies (Ullah 2013). KESC remained intact, and was privatized as it is (25.6% still under GOP, while 71.2% was transferred to a foreign consortium) and is linked to the remaining system for electricity purchase only (KESC 2012).

Unbundling of WAPDA resulted in creation of 10 distribution companies (DISCOs), 4 generation companies (GENCOs), with thermal power generation license, and a transmission company, National Transmission and Dispatch Company (NTDC) (ICCI 2011). However, hydel generation was still under the control of WAPDA. The figure 3.4 illustrates the surgery in a simplified manner. At present, components in dark background are the unbundled parts of WAPDA. Electricity is generated by independent power producers (IPPs), GENCOs and WAPDA and sent to NTDC grid, after which it is distributed by the DISCOs to the consumer end.

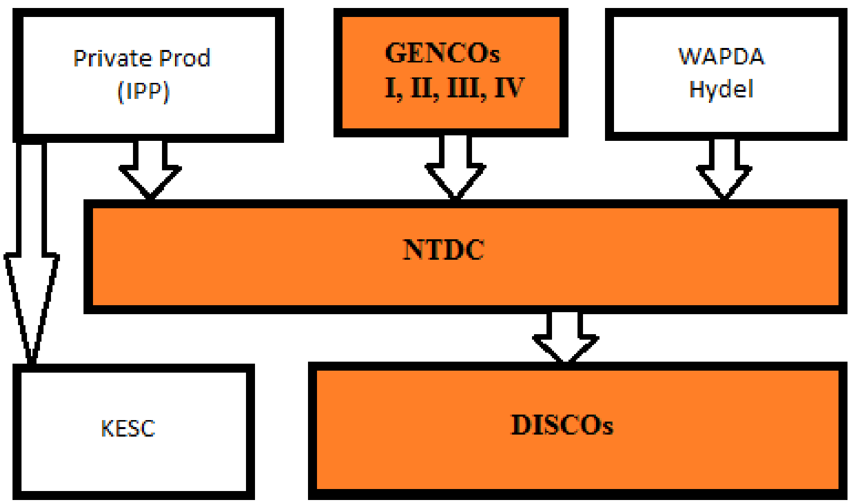

Figure 3.4 Managerial structure of Pakistan's electricity sector 2015

Regions of Pakistan are sub-divided into 10 DISCOs of each division which supply electricity to their corresponding areas. The KESC handles its own distribution and transmission responsibilities, and is connected to a few private thermal plants (IPP's) for electricity purchase. Besides the efforts of the government to utilize the benefits of privatization, only thermal generation is subjected to privatization, even to this day.

To manage this whole newly formed system under the Power Policy of 1997-98, Pakistan Electric and Power CO. (PEPCO), a separate agency within WAPDA, was created in the same year. It was aimed to consolidate the organizational setup, and induce coordination and integration between the thermal generation (GENCO's), distribution (DISCO's) and transmission (NTDC) bodies. All the thermal power plants operated by the GENCO's comes under the command of PEPCO. The Central Power Purchase Agency (CPPA) was also setup in 1998 to coordinate the payments within the structure. Again, under the 1997-98 law, private investments in thermal generation were promoted. Hence, the system remained to be a public monopoly therefore, another body was formed to regulate the public sector entities in 1997 i.e., National Electric Power and Regulatory Authority (NEPRA). Malik (2010) noted that "*National Electric Power Regulatory Authority (NEPRA) was created under the NEPRA Act 1997-8 to ensure fair competition and consumer, producer and seller protection*". Coherently, to monitor the side of private sector of power, Power Infrastructure Board (PPIB) was formed, providing added security and incentive measures to the private entrepreneurs, both existing and potential. The deregulation of the sector has been assessed in a number of studies, but the conclusion remains the same that although the expectation was positive, but the results have been almost fruitless.

After the Power policy of 1998, a number of new policies were introduced in 2002, 2006, 2008 and 2013 consisting mainly of promotions to attract private sector for mining indigenous resources (mainly hydel) and to facilitate public as well as public-private partnerships. According to my assessment of these policies, only minor changes have been made from the original Power Policy of 1998 which was discussed in details. It is not much worth going into the details of these policies.

Recently, a U.S based company known as Hagler Bailly Pakistan Ltd. is working with the GOP and private power producers to propose insightful endeavors, both in generation and transmission sector. Evaluation is being conducted by Hagler Bailly with other firms to privatize three of the GENCO's, including GEPCO, LESCO and IESCO. Also a new power system model is being developed by Advanced Engineering Association International (AEAI) and Hagler Bailly to improve the overall electricity structure (Hagler Bailly Pakistan 2014).

As far as the nuclear setup of Pakistan is concerned, the Pakistan Atomic Energy Committee (PAEC) was established in 1955. It is a government authority which owns and operates the three existing nuclear power plants. Construction of the first plant started in 1965 and the production commenced in 1972. After this, two more plants were established in 2000 and 2011. Pakistan is yet to reach its ambition on developing 8000+ MW of nuclear capacity.

3.3 Power Plants and Installed Capacity

A power plant is a unit which converts primary energy into electricity through mechanical motion. In Pakistan, fossil fuels such as coal, oil, and gas, hydro, nuclear, renewables such as wind and solar are used to generate electricity. Generally, almost all the Hydro plants are owned by the government. For thermal plants, the IPP's have a larger share (in terms of number of plants as well as installed capacity). The nuclear plants present in Pakistan are under the ownership of PAEC. As for now, there is no notable development in the renewable sector (wind and solar) but the GOP is actively working on new frameworks to bring in the use of renewable energy to make the energy mix more sustainable. Most of the data in this section is collected from the State of Industry Report 2014 by NEPRA.

The details of some major power plants are given in the Appendix B. More details including power plant-wise generation, capacity, capacity factor and cost of generation are all included in table C.6 in Appendix C. Technical specifications of thermal plants are provided in table C.7 in Appendix C.

A considerable growth of generation capacity can be seen during the lifetime of the country from 60 MW in 1947 to 25348 MW in 2014. The main sources of power generation are thermal and hydro, while the minor ones include nuclear and renewables. In 2014, thermal was 68%, hydro 28%, nuclear 3%, wind 1% and solar <1% of the total installed capacity. Table 3.1 gives the installed capacities from 2010 to 2014 of each type of power plants.

Year	**Hydro**	**Thermal**	**Nuclear**	**Wind**	**Solar**	**Total**
MW						
2010	6555	14795	462			21812
2011	6645	16009	787			23441
2012	6729	16089	787	1		23605
2013	6947	16042	787	50	0.1	23825
2014	7117	17209	787	235	0.1	25348

Table 3.1 Source-type installed electric generation capacities, 2010-014

In thermal power plants, the major chunk of power generation resource is furnace oil, diesel and natural gas. This means that Pakistan's electricity is mostly produced from an expensive means, as most of the crude oil and oil products are imported. After the privatization law of 1985, the GOP had amended the power law in such a way as to attract a market based power economy, which flooded investments in power plants that use fossil fuels such as oil and gas (NEPRA 2014).

Meanwhile, only minor hydro generating units are open for privatization which resulted in a stunted growth of this sector. The nuclear alternate is totally in the hands of the government and the sector could not grow due to continuous economic and political crisis. As for the renewable energy resources, such as wind and solar, only recently the Alternate

Energy Development Board (AEDB) has been established to help promote sustainability with integration of these renewable resources into the energy mix.

Figure 3.5 indicates that there was a satisfactory growth in both hydro and thermal power generating capacities until around 1995. After this period, it can be seen that increase in only thermal capacity is present, while the rest are almost stagnant.

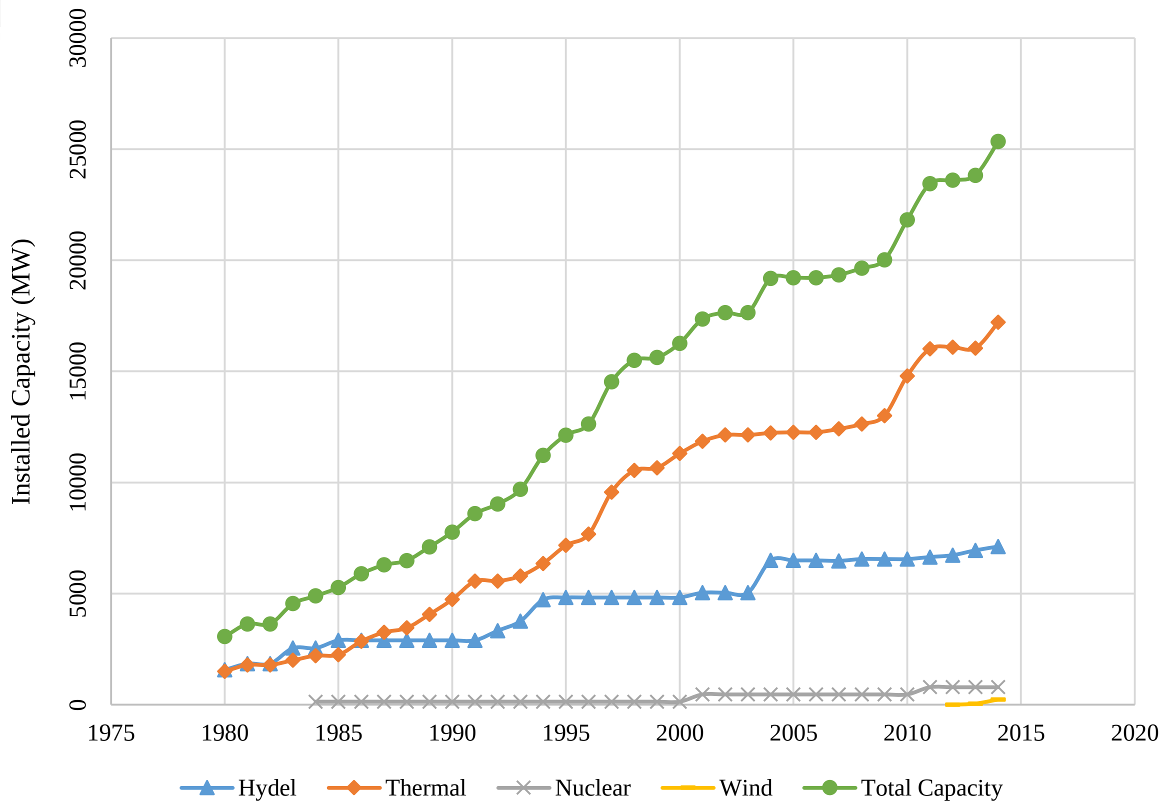

Figure 3.5 Capacity growth, 1980-2014 (tabular data provided in table C.1 in Appendix C)

In fact, the graph of overall capacity is similar to that of thermal capacity, which tells the close dependence of power generation on fossil fuels. Up until 1988, thermal and hydro installed capacities were approximately the same but thermal capacity started to rise and the gap started to increase further and further as new thermal plants were developed while nothing new was being done in the hydro sector. The gradient of total capacity increases after 1993 due to commissioning of new IPP power plants, and continues up until 2004, after which the country started to face major power shortages. A stunted economic advancement and unsteady government hampered the growth of power sector explained by the low gradient between 2004 and 2009, when no major additions were made to the total installed capacity. With the change of government, the period between 2010 and 2012 saw improvements and can be seen by the increasing gradient. About 10 new thermal power plant projects were commenced in this period, giving considerable rise to the installed capacity.

The small rise in hydro capacity at around 2003 is due to building of the Ghazi Barotha dam in 2003, and after that no major projects have been developed except small private hydro plants. The nuclear capacity line shows that there has been almost no increase in this sector. Only recently there has been some development in the renewable sectors of solar and wind after the establishment of the AEDB. The total capacity shows a general rise, but this amount of expansion has been insufficient to meet the demand and supply. In hypothetical sense, this line should match the characteristics of an exponentially growing one (a continuously increasing gradient) in order to maintain continuous electricity supply to the ever-growing population and demand of the country. The data shows an average increase of 655 MW of capacity per year.

Figure 3.6 shows the share of total generating capacity between public and private sector in the PEPCO area (KESC is excluded). Tabular data provided in table C.2 in Appendix C. In the PEPCO area (all Pakistan except Karachi), generation is contributed by thermal, hydro and nuclear. Although there are over 30 thermal IPP’s in the PEPCO area, still the larger share of total generating capacity belongs to the government. This is due to the government ownership of all the hydro plants present in the country.

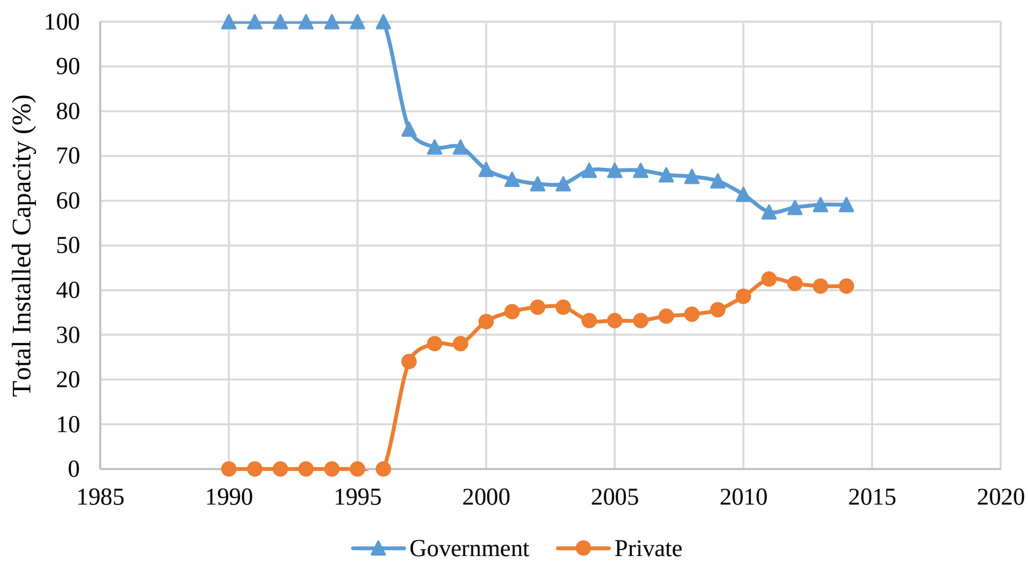

Figure 3.6 Public-Private total capacity ownership in PEPCO area, 1990-2014

Major contribution of IPP's generation into the electric grid started in 1997, with the commissioning of KAPCO and HUBCO power plants. The trend continued to increase up until 2003, where the capacity share of private ownership decreased due to the commencement of the new public owned Ghazi Barotha hydro plant, which contributed 1450 MW capacity. The trend again started to increase as new IPP's were adding to the grid till 2011, after which there has been no new private investment in the thermal sector. Meanwhile a few additions were made to the publicly owned power plants (CHASNUPP nuclear Extension, Khan Khwar hydro plant and Jinnah hydro plant) which explains the slight downfall of IPP share and increase in public share of the total capacity after 2011. Currently, 41% of share is held by the IPP's and 59% by government in the PEPCO area.

Thermal Generation Capacity

Thermal power generation has a capacity of 17,209 MW and contributes to 67% of the total mix. This is due to the large private share, showing that the government gave impetus to private establishments.

Currently, private share is 65% compared to 35% of the public sector in terms of capacity, as shown in figure 3.7. The trend of private owner-ship is an increasing one. After mid 1990's, the increase has been maximum. From 1995 to 2000, an increase of 4024 MW can be seen in IPP's capacity, and in a span of 34 years, 462 MW of thermal capacity is added each year on average basis. As mentioned in the previous section, the total increase of capacity per year has been 655 MW which makes thermal contribution of 70% in terms of this increase (this only is the contribution of IPP's in the total rise in capacity per year). The sharp increase in IPP's capacity in the year 2006 is because of the privatization of KESC, when all their plants were handed over to a multinational firm, The Abraaj Group (Abraaj 2015).

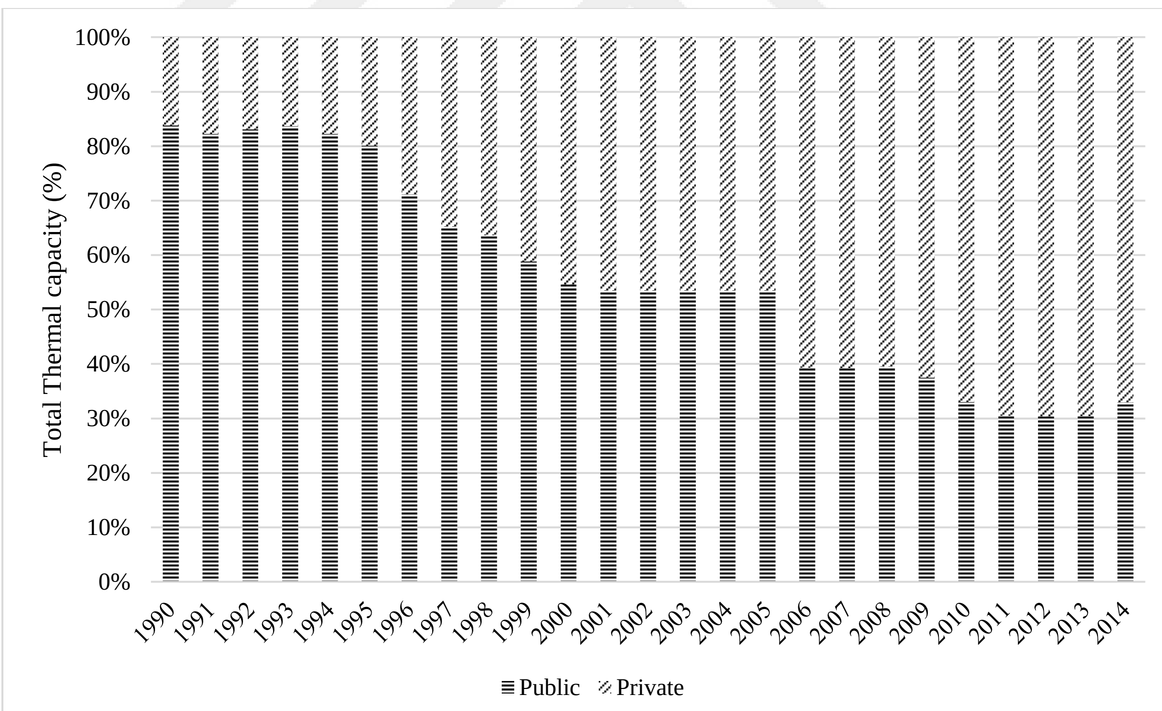

Figure 3.7 Public-Private thermal capacity ownership, 1990-2014

The public sector has, however, seen less development through time. From 1990 to 2014, an increase of 1588 MW is seen. This makes a per year average increase of 106 MW. A few number of power plants have been added under the GENCO's after early 1990's, and they generally have lesser generation efficiency compared to the IPP's plants. The installation of a new unit in Guddu Plant and building of Nandipur Power Project contributes to the slight increase in public capacity in 2014 after 8 years. All these facts points to the direction that the GOP is not interested, or unable to, in investing into new power projects. Other facts include depletion of natural gas and expensive import of oil.

Hydro Generation Capacity

At present, the total hydro installed capacity is 7117 MW, which is a minute number compared to the so-called 65,000 MW potential. The only major exploitation of this indigenous resource are through the three main power dams namely Tarbela, Mangla and Ghazi Barotha, summing up a total generation capacity of 5928 MW. This is approximately 24% of the total installed capacity installed in the country.

WAPDA is the sole owner of the hydro capacity installed as can be seen in figure 3.8 except a mere 214 MW owned by independent parties. In a span of 15 years, the hydro capacity has risen from 4809 MW to 6733 MW, indicating an average increase of 128 MW per year. The figure indicates that the government is adamant in holding the hydro sector, as only around 3% of the capacity is owned by the independent parties. Before 2007, there was only one private hydro project in operation which is Jagran Dam of 30 MW installed capacity.

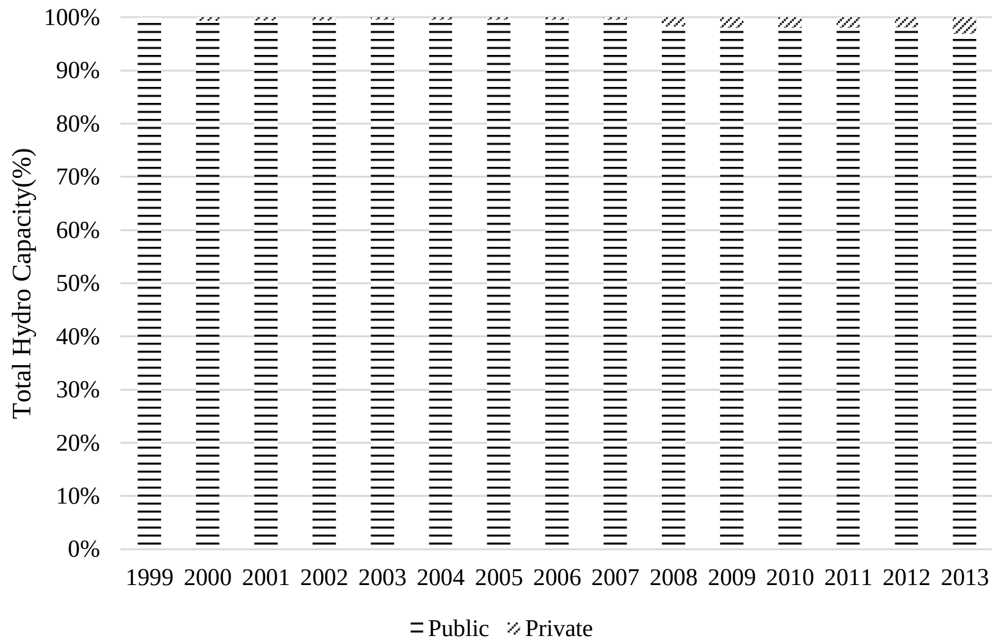

Figure 3.8 Public-Private hydro capacity ownership, 1999-2013

Nuclear Generation Capacity

Currently, the total installed capacity of nuclear is mere 787 MW. Not much development has been made in this sector since its introduction in 1972. Initially, only 137 MW of capacity was installed, which grew to 462 in 2001 when the CHASNUPP power plant was inaugurated. The latest development is the CHASNUPP Extension which provides another 325 MW summing the total to 787 MW.

Renewable Generation Capacity (Wind & Solar)

This sector is clearly yet to be exploited, as can be seen from figure 3.5. At this time, 235 MW of wind generation capacity is installed. This sector is under experimental phase, and might turn out to be one of the problem solvers for Pakistan's energy problems. The Quaid-e-Azam solar park has a capacity of 1000 MW but it is yet to be operational. In

2016, the total renewable capacity is to be increased to approximately 1500 MW according to the GOP.

3.4 Electricity Generation

Generation review is very much analogical to the installed capacity, which means that the main source of increase in power generation are the fossil fuels, while the hydro sector has remained pretty much unchanged since 1990. The historic power generation trend can be seen in figure 3.9. Detailed tabular data given in table C.4 in Appendix C. In the year 2014, 106,051 GWh of electricity was generated out of which 68,196 GWh was produced by thermal plants. The GOP has stopped issuing license for new natural gas power plants, which means that the oil industry will be further burdened and generation will continue to be expensive because of oil imports (GOP 2015).

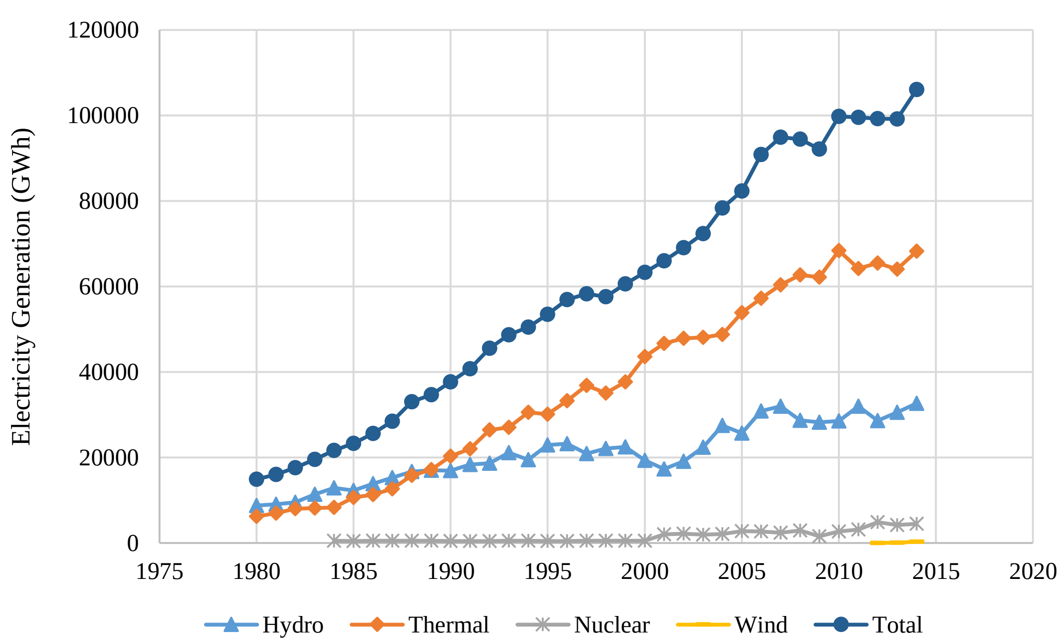

Figure 3.9 Electricity generation, 1980-2014

The average increase of generation per year is 2681 GWh from 1980 to 2014. The general trend of total generation is an increasing one, other than the two crests in the year 1998 and 2009. This is not due to drop in installed capacity (which has been consistent or increasing in these years) but due to the low plant utilization factor observed in these years and lack of availability of fuel (NEPRA 2014). The total generation trend closely follows that of the thermal generation, indicating the close dependence. The thermal generation saw a slight drop in recent years due to the following reasons (NEPRA 2014):-

i) Shortage of locally harvested natural gas
ii) Increasing inefficiency in the public sector power plants
iii) Non-operational units of the public sector power plants

Increase in power generation per year on average basis in the thermal sector is 1824 GWh, which is 68% of the total increase per year. The generation of hydroelectricity sector has seen less increase compared to thermal. The average increase per year is 704 GWh, which is 26% of the total increase of 2681 GWh. It can be seen that before 1989, more electricity was generated by hydro power compared to thermal. After this, the electricity structure of Pakistan started relying more on the fossil fuel based production which indicates that the government was more interested in quick solutions and short term planning rather than utilizing the indigenous hydro resource. In 2014, 32,673 GWh of electricity was produced by hydro plants which is 31% of the total generation.

The three nuclear power plants have not been a big impact on the total production statistics and produced 4501 GWh in 2014. The resources like wind and solar are yet to play a major role in the total energy mix, with a contribution of <1 GWh of generation (NEPRA 2014).

The shift from hydro based generation to thermal based can be seen in figure 3.10. Such major reliance on natural gas and oil is an alarming situation in current era, where prices are ever increasing.

The government has to re-route the system and balance this dependency between the other sources of generation. Building of major hydro plants is a major commitment and the GOP has clearly failed in doing so in the past two decades and hence bringing down the total share of hydro generation from 59% to 31% between 1980 and 2014.

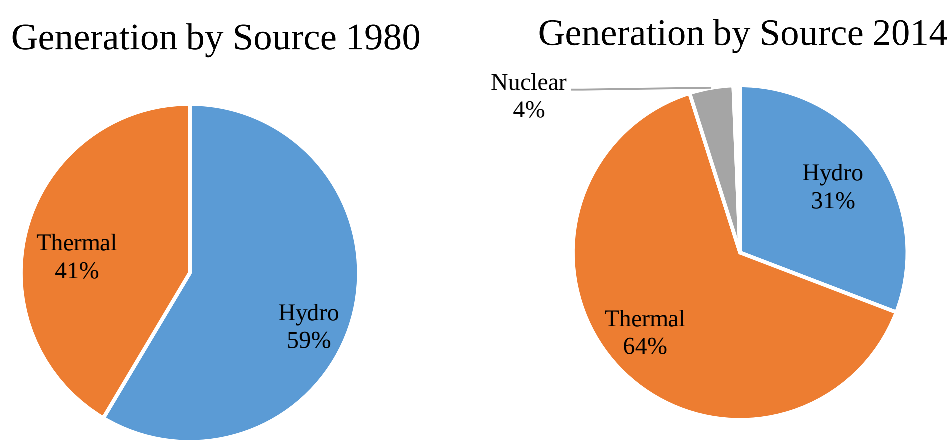

Figure 3.10 Generation source comparison 1980 and 2014

The highest generation and the percentage share power plant-wise for the year 2014 is given as (percentages are of total generation):

i) Hydro (public): Tarbela Dam 15178 GWh (14.3%)
ii) Thermal (public GENCO): Thermal Power Station Muzaffargarh 5132 GWh (4.8%)
iii) Thermal (private IPPs): HUBCO Power Project 7086 GWh (6.7%)
iv) Thermal (KESC): Bin Qasim Power Plant I&II 7405 GWh (7%)
v) Nuclear (PAEC): CHASNUPP-II 2208 GWh (2.1%)

These five generators alone accounted for 35% of the total generation in 2014, indicating their vital importance in providing electricity to the country's power grid. If any one of these generators may fail for one reason or the other, the country will face a major blackout until the error is fixed.

3.4.1 Fuel Consumption and Efficiency of Thermal Plants

This section will identify the amount of energy input, output and the overall costs involved in electricity generation. The data provided in the State of Industry Report 2014 by NEPRA contains data of only OPEX, which includes the operation costs only. By calculating energy input and output, an analysis on generation frequency is also provided in the coming sections.

Input Energy for Thermal Electricity Production

The discussion of primary fuels used to generate electricity including gas, oil and coal will be done in this section. The percentage of thermal installed capacity was 67% and generation 64% of the total in 2014. The statistics for different input fuels and their percentage shares are given in table 3.2.

Year	Unit	Gas	Fuel Oil	Diesel Oil	Coal	Total
2009	MTOE	7.83	7.21	0.17	0.05	15.26
	%share	51.3	47.23	1.14	0.33	100
2010	MTOE	7.1	8.34	0.26	0.05	15.76
	%share	45.08	52.9	1.67	0.36	100
2011	MTOE	6.49	7.83	0.1	0.43	14.47
	%share	44.88	54.1	0.73	0.3	100
2012	MTOE	6.7	7.2	0.2	0.46	14.19
	%share	47.45	50.8	1.43	0.33	100
2013	MTOE	7.08	7.34	0.22	0.28	14.67
	%share	42.28	50.04	1.5	0.19	100

Table 3.2 Fossil fuel input of thermal power plants, 2009-2013

Table 3.2 shows the high input values of energy from gas and furnace oil which accounts to more than 92.32% in 2013. Although most of the electricity produced is by coal in most of the countries, in Pakistan it accounts to an insubstantial value. As for the annual growth of input energy, there is no specific trend. In 2011, the growth value dropped by 8.22% whereas the electricity produced was almost same as in the previous year. This indicates a possible decrease in losses, an improved generation efficiency or a combination of both and other key factors.

Figure 3.11 indicates that oil consumption has generally been consistent, except in the year 2010 during which electricity generation through thermal power was the highest in the history of Pakistan. The use of diesel oil is negligible compared to furnace oil and gas as there are very less generators which run on this type of fuel. There is only one coal powered generator which explains the small amount of coal used in the generation mix.

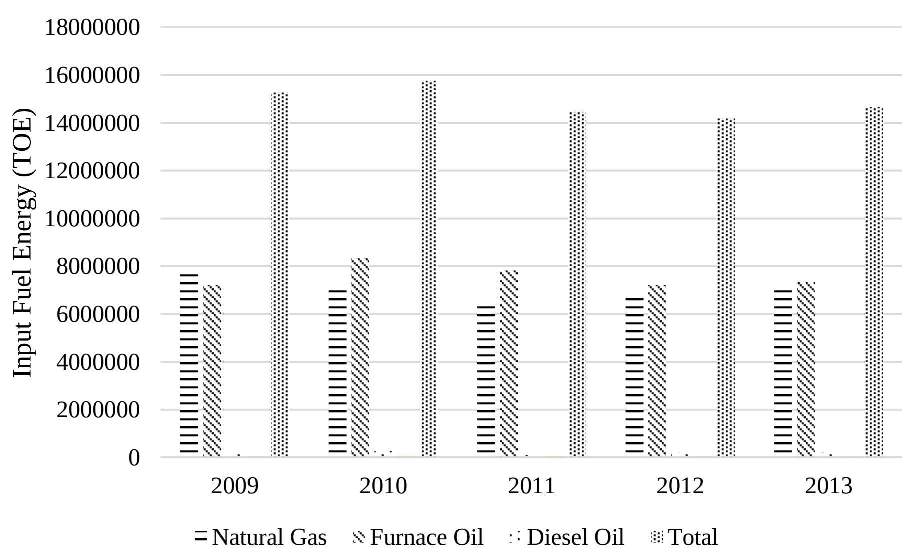

Figure 3.11 Input fuel energy for thermal electric generation, 2009-2013

The consumption of gas is controlled by the government and is planned to reduce because of its increasing unavailability. Some IPP's power plants for which the primary fuel was gas are urged to use the secondary fuel type which is diesel oil. The generation structure of the thermal sector is starting to be a less gas dependent one due to cancellation of further licenses for natural gas power plants and the government's urge to use secondary fuel for IPP's whose primary fuel is gas.

Output Electric Energy from Thermal Generation

The primary fuels including oil, gas and coal are directly converted to electricity by the power plants. Not all energy is converted to electricity, where heat is also a form of output. In some countries, this heat is sold for various purposes, but no such case has been seen in Pakistan. Corresponding to the inputs, the output follows the same trend, as shown in figure 3.12. Output generation from natural gas has decreased in recent years, while slightly increased from oil. Coal remains to be a negligible player in the output generation. The total output trend is almost consistent for the years between 2010 and 2014.

Year	**Unit**	**Gas**	**FO + HSD**	**Coal**	**Total**
2010	GWh	32557	35641	139	68337
	TOE	2799398	3064574	11952	5875924
2011	GWh	36489	28571	109	65169
	TOE	3137489	2456663	9372	5603524
2012	GWh	30162	35251	66	65479
	TOE	2593465	3031040	5675	5630180
2013	GWh	28191	35804	40	64035
	TOE	2423989	3078590	3439	5506018
2014	GWh	26790	41240	112	68142
	TOE	2303525	3546001	9630	5859156

Table 3.3 Thermal output energy by fuel type (1GWh= 86.04 TOE), 2010-2014

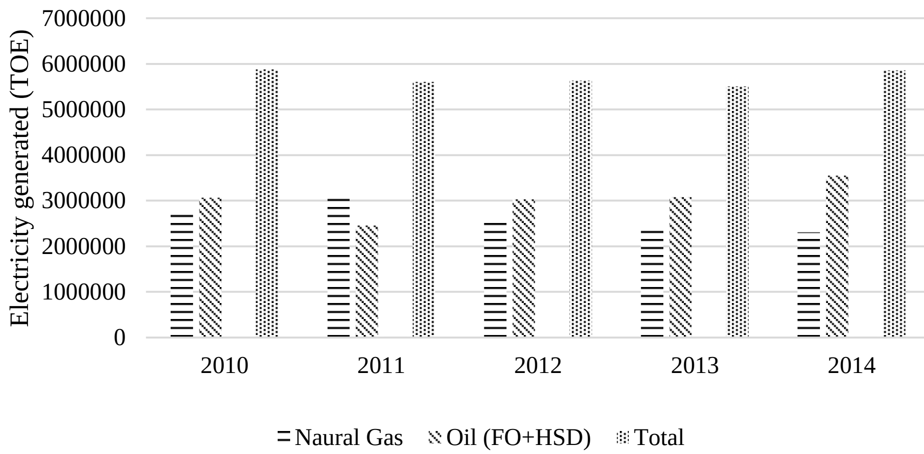

Figure 3.12 Output electric energy by thermal plants, 2010-2014

Efficiency of Thermal Power Plants (Input and Output energy comparison)

With the analysis of input energy and the output electricity, we can determine the overall thermal efficiency of plants. Figure 3.13 shows the improvement in thermal production efficiency of various countries. In a quick review, it can be seen that generally the efficiency of thermal plants is about 40-50%. Norway and Sweden have the highest efficiency reaching at 90% (although according to the European Environment Agency, there might be some error in this value). The output here is considered in terms of total electricity produced as well as any output heat sold to a third party.

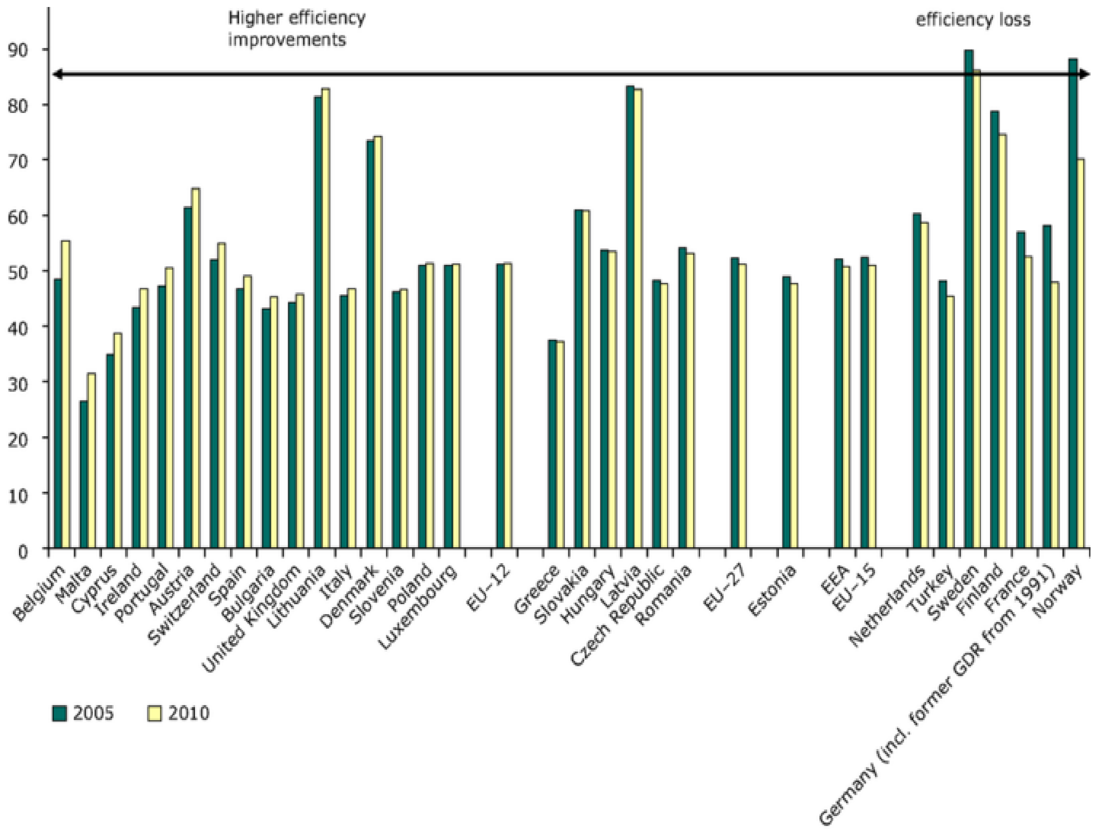

Figure 3.13 Improvement in plant efficiency world-wide (European Environment Agency 2015)

Year	Input (TOE)	Output (TOE)	Efficiency (%)
2010	15764932	5875924	37.3
2011	14469595	5603524	38.7
2012	14189587	5630180	39.7
2013	14673720	5506018	37.5

Table 3.4 Input vs output thermal energy, 2010-2014 (NEPRA 2014)

According to the input/output energy analysis in the case of Pakistan, the generation efficiency can be seen to be around 38% between 2010 to 2013. The rest of the 62% is either converted to heat/lost or used by the plant. This is a down side as in the case of thermal generation, the input fuel has to be bought or extracted compared to the already available ‘free fuels’ like hydro potential energy, solar energy and/or wind energy. The GOP buys most of the oil from international markets, further burdening the economic conditions of the country.

The efficiency needs to be checked as bulk power is generated by these power plants. According to the government statistics, the private sector shows a better overall performance in terms of efficiency compared to the public sector (NEPRA 2010). The major reasons for this are modern management practices and better and new equipment owned by the IPP’s compared to the public-owned plants. The government should adopt better managerial practices and come in par with the private sector, and also arrange for local as well as international inspection teams which can monitor the operation and provide feasible solutions and techniques to improve the overall efficiency.

3.4.2 Cost of Generation

In electrical power generation, the distinct ways of generating electricity incur significantly different costs. Primary data for generation and fuel cost is provided for hydro and thermal generation in the State of Industry Report 2014 by NEPRA in terms of OPEX only. However, the main focus is the thermal generation cost as the primary input fuel is coal, gas or oil and this has to be bought by a third party which results in an input investment. For hydro, the primary input is raw potential energy of water, which basically costs nothing. Cost analysis of the power plants is provided in the following sections.

Thermal Electricity Generation Cost

Due to lack of long term energy planning, Pakistan was forced to apply short term solution to meet the supply and demand of electricity through comparatively larger investment in thermal generation facilities after 1990's. This fact has ever since increased the burden on the delicate economy of the state, while recently this sector has started facing difficulty owing to the fact that the local natural gas reserves are almost finished and imports are further crippling the economy.

The cost of electric power generation through thermal means is relatively much higher than that of hydroelectric power generation. Although the initial cost of deploying a thermal power station is lower than that of a dam, but the operating cost is more due to purchasing of input fuel. Table 3.5 below shows sector wise production, cost/kWh and the total cost of production. Again, all the costs shown in this section are OPEX.

Sector	Year	2010	2011	2012	2013	2014
GENCO's	Generation (GWh)	19594	13021	12654	12873	13055
	Rs/kWh	7.9	9.3	10.6	11.7	13.6
	Total cost (million rupees)	155452	121555	134542	150500	176898
IPP's	Generation (GWh)	38836	42747	43155	41178	45086
	Rs/kWh	13.0	14.1	17.6	18.7	19.3
	Total cost (million rupees)	504744	604181	758125	768766	871910
KESC	Generation (GWh)	7964	7826	8029	8567	8764
	Rs/kWh	4.8	6.9	7.3	7.9	8.0
	Total cost (million rupees)	38035	53762	58423	67951	70281
Total	Generation (GWh)	68337	64152	65480	64035	68196
	Rs/kWh	10.2	12.2	14.5	15.4	16.4
	Total cost (million rupees)	698231	779498	951091	987218	1119090

Table 3.5 Thermal generation cost, 2010-2014 (data taken from State of Industry Report 2014 by NEPRA)

Cost differs considerably between IPPs, GENCOs and KESC. The cost/unit of the IPP's is the highest, ranging from 13-19.3 Rs/kWh from 2010 to 2014. The lowest is given by KESC, ranging from 4.8-8 Rs/kWh for the same range of years. The average costs/kWh for these 5 years are:

1. IPP's: 16.5 Rs/kWh
2. GENCO's: 10.6 Rs/kWh
3. KESC: 7 Rs/kWh
4. Total country: 13.7 Rs/kWh

As mentioned previously in this study, the largest chunk of thermal generation is contributed by the IPPs, which means that most of the generation is from expensive means. According to figure 3.14, the cost gradient lowers because of decrease in worldwide cost of oil. Although generation by the GENCO's sector is cheaper, but it contributes much less power to the grid, and is comparatively less efficient. The plants under this sector are the base load plants, which basically explains the cheaper cost. If this sector can further be developed, the overall generation cost can be lowered. But sadly, this sector has been stunted since long ago, and the GOP is aiming to privatize it.

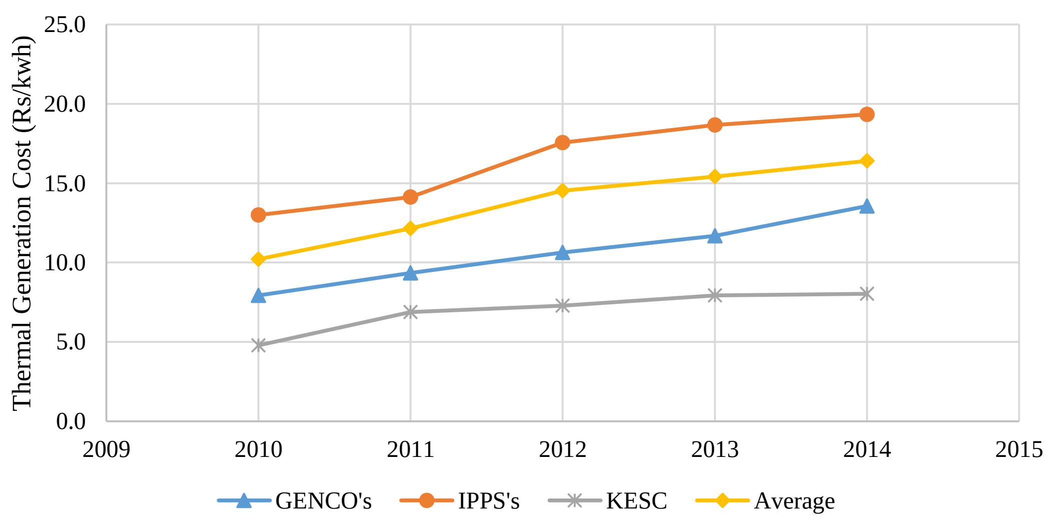

Figure 3.14 Thermal generation cost comparison between GENCOs, IPPs and KESC, 2009-2014

Hydro Electricity generation Cost

The main cost involving a hydro setup is the plant construction cost, dam building cost, clearing land and resettlement costs etc. There is a minor operating cost which may include labor cost, maintenance and repairs and other miscellaneous costs which do not add up to a high amount. Especially in developing countries like Pakistan, this helps relieve economic burden as there is no need to import primary fuels such as fossil fuels and uranium. It also helps to prevent flooding and provide water for irrigation, which further helps the vast agriculture setup of Pakistan.

Table 3.6 shows the cost involved in generation. In NEPRA's report, total cost is provided and generation are provided, making it possible to calculate RS/kWh. The cost varies between 0.9-1.1 Rs/kWh. According to the latest conversion rate from Rupees to US Dollars, this cost is between 0.01-0.02 USD/kWh approximately. Considering the small deviation of the values, the trend is more or less consistent throughout the years.

Year	Generation (GWh)	Rs/kWh	Total Cost (million rupees)
2010	28492	0.9	24445.3
2011	31990	0.9	28201.8
2012	28601	1.1	31023.0
2013	30524	1.0	31665.4
2014	32673	0.9	30959.6

Table 3.6 Hydro electricity generation cost, 2010-2014

The cost of generation is considerably lower than that of thermal generation, with an average of 1 Rs/kWh. However, the main issue which is faced to build a new dam is the high construction cost, landscape planning issues and economic burden due to this high cost. Conclusively, there are long term benefits for building a dam but the economy may suffer in view of short term period.

3.4.3 Capacity Factor

The capacity factor is described as:

$$Capacity\ Factor\ (CF) = \frac{Generation\ (GWh)}{Installed\ capacity\ (MWh) * 24hrs * 365days}$$

It is basically a ratio between the actual outputs over a period of time, to the potential output if full capacity is utilized. In Pakistan, the combined capacity factor is close to the 50% value according to statistics from NEPRA, and this signifies that half of the power plant potential is utilized.

Figure 3.15 shows the source-wise capacity factor of the power plants in Pakistan. Before 1995, the capacity factor of hydro plants was comparatively higher but after addition of new generator units in these plants, the capacity factor dropped due to possible reasons like less efficient machines. The CF value for thermal plants is non-changing as this is the main source of electricity and the operation statistics have therefore been consistent. For the nuclear plants, the value shows a rise after 2000. The nuclear plant technology generally has a higher CF value, and after the electricity shortage that hit Pakistan, the GOP decided to increase this to a considerable potential.

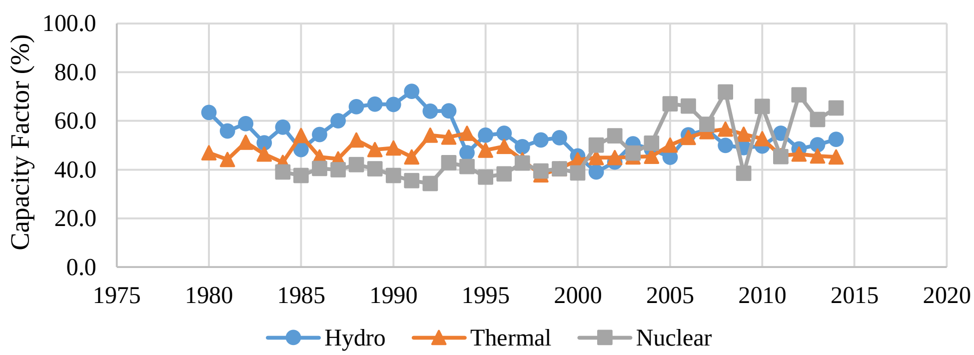

Figure 3.15 Source-wise capacity factor, 1980-2014

The value of CF varies from fuel type and the design of the plant. Plants always have a CF of lower than 100% due to the following reasons (EIA 2015).

- A plant can be out of service due to equipment failure or routine maintenance. This can be seen more in the case of base load plants, as they are operated continuously at high output due to the lower cost per unit. In the case of Pakistan, the plants under the GENCOs are prone to lower CF values.
- Output may be cut down when electricity is not needed or because the price of electricity maybe too low to have an economical production. This is mostly in the case of peaking power plants, which operate very less throughout the year as their electricity cost is higher.
- When there is an addition of generator unit in hydro dams. The fuel energy remains same but peak generation output is increased while CF decreases

3.5 Transmission and Distribution of Electricity

This section includes the discussion based on the transmission by the NTDC and distribution by the DISCOs. According to many studies and speculations, the transmission and distribution sector of Pakistan is the worst performing once, with huge energy and financial losses. It is therefore insightful to examine the performance of this sector in order to point out the reasons for this under-performance.

3.5.1 Transmission

Transmission is the nervous system of the electricity supply chain with high and extra high voltage lines. Generation plants are connected to demand centers by a well-organized network including power transformation stations and control centers. Currently in Pakistan, there are two companies engaged in the transmission industry. One is National Transmission and Dispatch Company (NTDC), which operates in the PEPCO area and is a public sector company, and the other is KESC, which operates in Karachi and its surrounding areas and comes under the control of private sector. According to the government statistics, the NTDC carries the role of transmitting power from generating stations to distribution companies through a network of 500kV and 220kV power lines.

Presently, NTDC consists of 13 grid stations with 500 kV lines, and 35 grid stations with 220 kV transmission lines. The total length of 500 kV lines are 5183 KM, and 220 kV are 9104 KM (NEPRA 2014). In addition to this, KESC operates 75 grid stations and 1248 km of transmission lines (including 220kV, 132 kV and 66 kV) which are both overhead and underground lines (NEPRA 2014). The high voltage lines are stretched from north to south along the Indus River Valley area, which consists of majority of the population of Pakistan. However, the spread of transmission does not cover the whole land and around one third of the population does not have access to electricity (Padgett 1992). Figure 3.16 shows the major power lines across the country. The most scarcely fed area is the province of Baluchistan and with the least number of electrified village, while Punjab has the highest number of electric facilities. (Aamir 2016) realizes in his report that the electric demand of Baluchistan region is 1650 MW, while only 300-400 MW is supplied. This causes damage to the agriculture sector at a great level as 80% of the population's livelihood is dependent on this.

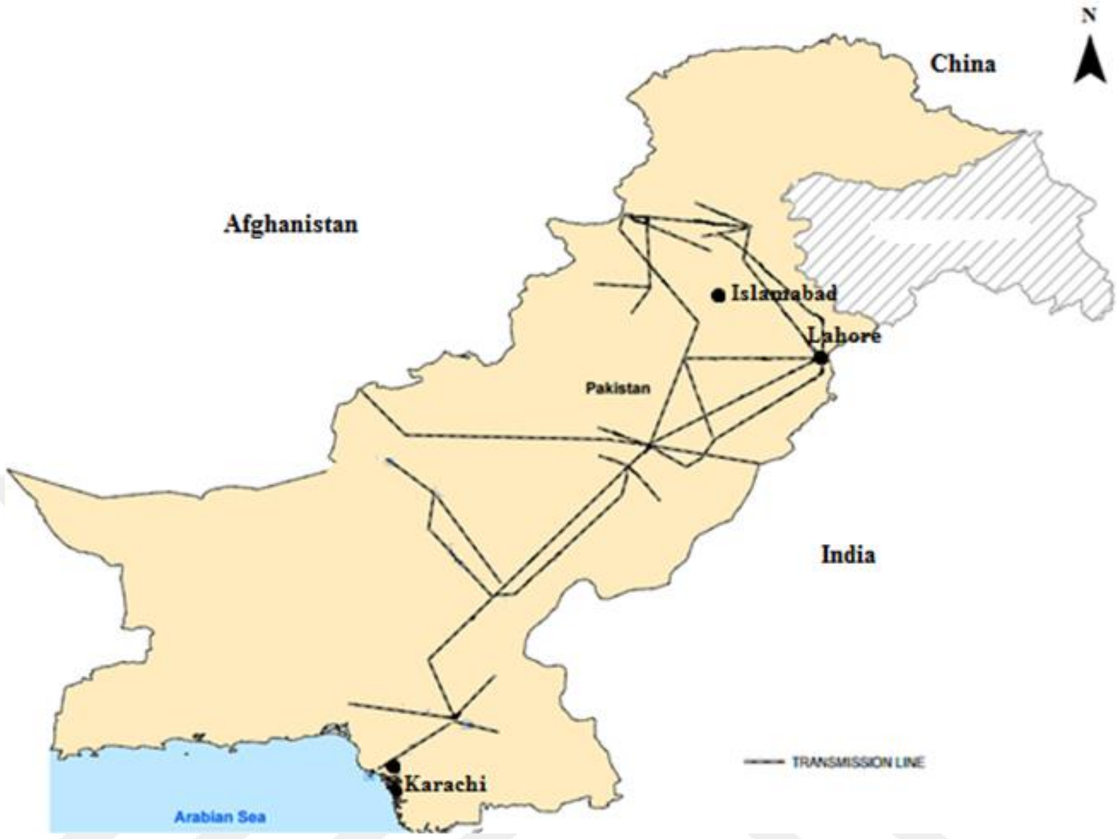

Figure 3.16 Transmission line network in Pakistan map

Correct utilization of the transmission lines and power transformers plays a significant role in technical and financial terms. If the system is underutilized, transmission companies may face a financial loss due to lack of utilization, while if it is overloaded, the hardware can be damaged. The performance standards of T&D will be discussed in subsequent topics.

3.5.2 Distribution

After the unbundling of WAPDA in 1997-98, the distribution system gained a separate status. Currently there are two vertically integrated systems in operation which are:

1. Distribution Companies (DISCOs) operating under PEPCO for all of Pakistan except Karachi.
2. KESC's own distribution system which provides services to Karachi and its adjoining areas.

A number of previous studies offer details about the distribution sector. Ullah (2013) and Rauf et al. (2015) describes the structure and duties of the distribution companies. The DISCOs are responsible for correct and efficient distribution of electricity, the primary role being operation, maintenance and development of grid stations and transmission networks of 132kV and below. These companies purchase electricity directly from NTDC, which is the transmission company as described earlier. KESC's distribution system is connected to its own transmission system, and does not deal with inter-company sale/purchase. The end users of these distribution companies are classified as residential, commercial, industrial, agricultural and street lighting. The table 3.7 gives a brief information about the distribution companies in Pakistan.

Company		**Number of Consumers**	**Service Area(Sq.Km)**
Public Distribution Companies			
PESCO	Peshawar Electric Supply Co.	2,867,778	74,521
TESCO	Tribal Areas Electric Supply Co.	441,480	27,220
IESCO	Islamabad Electric Supply Co.	2,379,302	23,160
GEPCO	Gujranwala Electric Supply Co.	2,824,053	17,207
LESCO	Lahore Electric Supply Co.	3,712,586	19,054
FESCO	Faisalabad Electric Supply Co.	3,288,930	36,122
MEPCO	Multan Electric Supply Co.	4,860,296	105,505

HESCO	Hyderabad Electric Supply Co.	952,263	81,087
SEPCO	Sukkur Electric Supply Co.	712,196	56,300
QESCO	Quetta Electric Supply Co.	548,980	334,616
Private Distribution Companies			
KESC	Karachi Electric Supply Co.	2,111,336	6,500
BTPL	Bahria Town (Pvt.) Limited	15,636	n/a

Table 3.7 Distribution companies in Pakistan (NEPRA 2014)

There are a total of ten public DISCOs, as shown in figure 3.17, and two private distribution companies. The DISCOs are administered by PEPCO and NEPRA combined, while KESC handles its own distribution responsibilities. The TESCO and SEPCO are newly formed companies and were made because of increasing demand of the areas they work in. Before these two, the adjoining area's company was responsible for supply. PESCO was distributing in tribal areas and HESCO in Sukkur and adjoining areas before the creation of these two new bodies.

Bahria Town is a private housing society owned by Mr. Riaz Malik. It was developed in 1996 and holds an asset worth of US$20 billion (Bahriatown.com 2004). It provides the residents through its own grid stations. This is the only residential area in Pakistan which does not face load shedding and power outages. It was granted the distribution license in 2010.

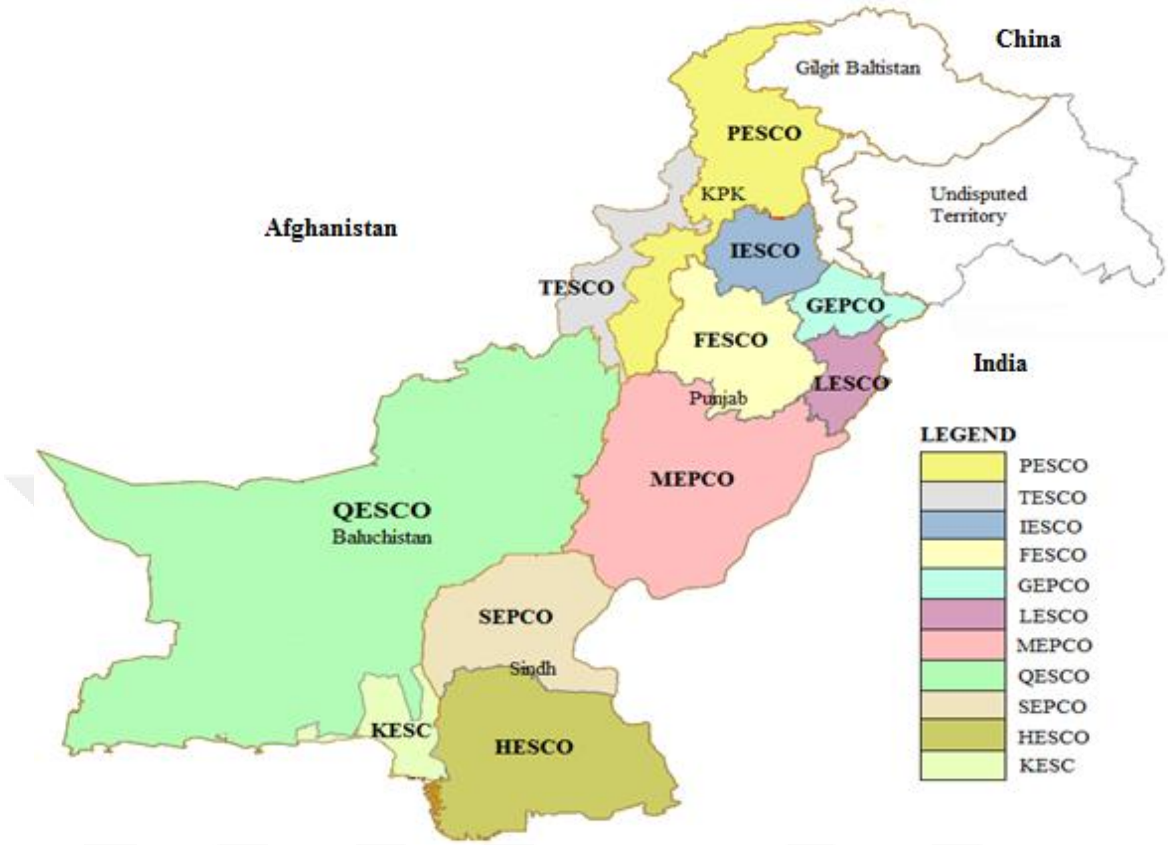

Figure 3.17 Distribution companies operating areas map (NEPRA 2014)

Besides these distribution companies, there are other numerous private ones also, including Bahria town. Most of them supplies power to their partner companies or sell to NTDC at a very small scale. One of the companies, Engro Chemical Pakistan limited, is a captive power producer and was given distribution license by NEPRA in 2009. A captive power producer generates and distributes electricity for self-consumption. The performance in terms of System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) of the DISCOs are analyzed in Appendix E.

3.5.3 Transmission and Distribution Losses

This section will give an insight of the losses faced of transmission and distribution system of Pakistan. The generated electricity passes through huge complex networks, including lines, cables, transformers and grids, in order to reach the end users. When this electricity is transmitted, some energy is lost as heat and other forms and it is technically impossible to evade this loss at hundred percent level.

The two main types of losses can be summarized as (EEP - Electrical Engineering Portal 2013):

1. Technical losses: These are the inevitable losses resulting from energy dissipation from electric components such as wires, resistors, transformers etc. These losses cannot be fully cancelled but can be diminished by using better equipment and techniques, such as high voltage-low current transmission throw long lines.
2. Non-technical losses: This type of loss can be categorized as power theft, metering errors and data error. These losses can be evaded by better management, public awareness and control, law implementations etc.

The difference in the generated and billed amount is the overall loss of energy, and is calculated as:

$$T\&D\ losses\ (\%) = \frac{Energy\ input\ to\ feeder\ (kWh) - Energy\ billed\ to\ consumer(kWh)}{Energy\ input\ (kWh)}\ x\ 100$$

Distribution losses play a major role in the overall loss of energy in Pakistan. They are generally accounted for 50% of the total losses. In Pakistan, the distribution losses go as high as 20% of the total energy (Ullah 2013). The main players of the distribution losses in Pakistan are the poor performing distribution companies, lack of technical expertise, old equipment and theft (Rauf et al. 2015).

Figure 3.18 shows the transmission losses versus units for transmission (in GWh) for the NTDC system (KESC not included). A slight improvement in the transmission losses is seen during the last 10 years. In 2004, the transmission losses were 5054 GWh (7.5% of total) compared to 2327 GWh (2.5% of total) in 2014, and they are decreasing with increasing energy input. This indeed is a considerable improvement, keeping in view the ever deteriorating overall conditions of the electricity infrastructure of the country. This improvement accounts to the better performance standard of the NTDC, both management and technical wise, in the recent years (NEPRA 2014).

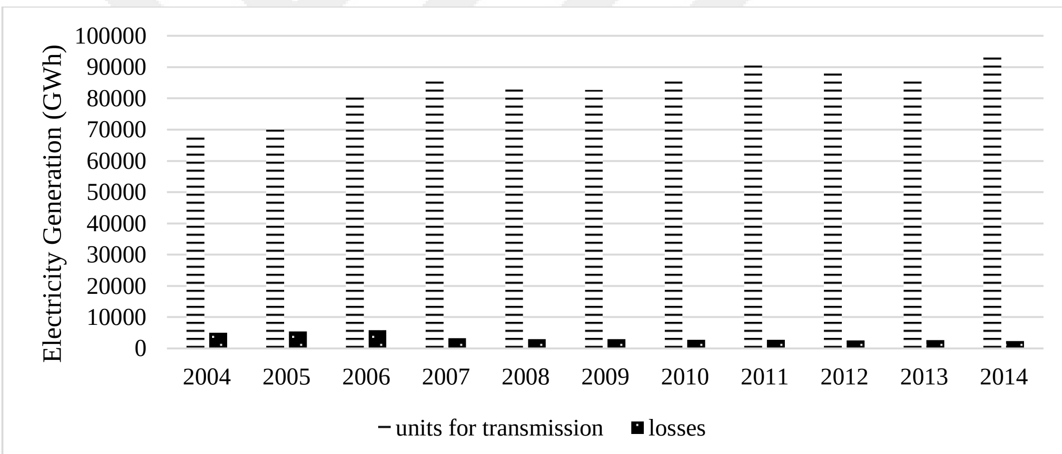

Figure 3.18 Units generated vs transmission losses, 2004-2014

Coming to the weakest link in the losses section, the distribution losses, the data illustration is shown below for public DISCOs (KESC not included) in figure 3.19. In 2014, the distribution losses accounted for 16278 GWh compared to 11151 GWh in 2004. This indicates that the distribution companies are not considering any improvement measures and these losses are ever increasing. These losses accounts for total wastage, and to evade or diminish these losses, the distribution companies should take considerable actions.

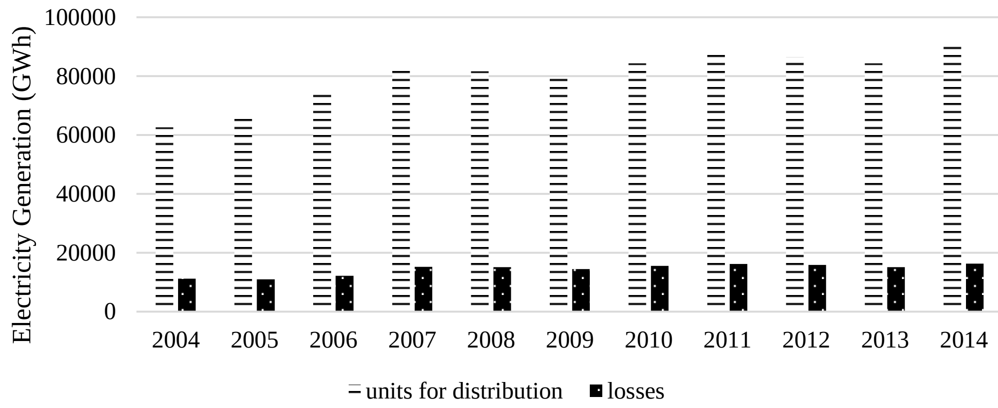

Figure 3.19 Units for distribution vs distribution losses, 2004-2014

A comparison of the transmission and distribution losses is shown in figure 3.20 in terms of percentage for public DISCOs (KESC not included). It can be seen that there is no improvement in the distribution losses, and the decrease in the overall losses is the result of decreased transmission losses. The distribution losses are mainly non-technical ones and surely these can be evaded if necessary actions are initiated.

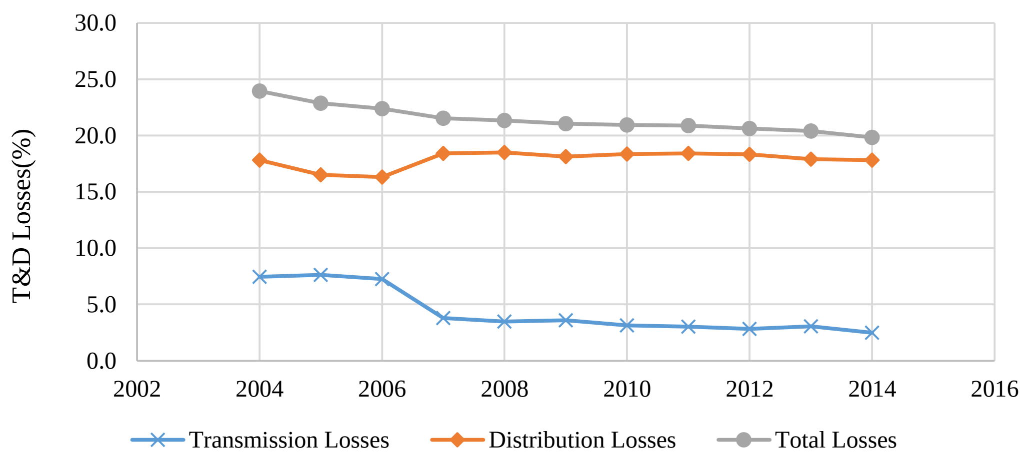

Figure 3.20 Transmission, distribution and total losses, 2004-2014

In first world countries like Germany, France and UK, the T&D losses are less than 10%, compared to 20% in Pakistan. Considering the fact that there is already a power deficit in Pakistan, these extreme losses pulls down the effort of improving the supply and demand gap. As a first step, the GOP should consider an overhaul to minimize these losses if any steps are to be taken in improving the power system of the country.

3.6 Demand and Consumption of Electricity

The consumption is mostly saturated in the urban areas of Pakistan, as most of the domestic, industrial and public lighting sector lies here. Improved lifestyles and increased income of people has led to a greater demand in these urban areas. This is proved by the fact that about 60% of the total electricity is consumed by the Punjab region, the most developed part of Pakistan (Nepra 2014). Karachi is also one of the leading regions in terms of development and consumption, but rest of the Sindh province has a considerably lower electricity demand and consumption. Perwez et al. (2015) points out in their study that 164,532 number of villages were electrified in the period between 1983-2010, while industrial sector consumers growing at a rate of 2.58% annually, the resulting demand of electricity has risen to a mammoth amount. However, the supply side fails to comply, resulting in an ever increasing supply and demand gap.

3.6.1 Demand and Supply

Figure 3.21 shows the demand of electricity in the country. The data is divided into per day values of maximum demand, maximum demand diversified and average demand. The maximum diversified demand is the average of maximum demands in different periods of winter and summer time. The values of these demands are taken from the State of Industry Report 2014 by NEPRA. They can be calculated by registering the total time of blackouts and brownouts, and determining the amount of electricity that is needed in these times.

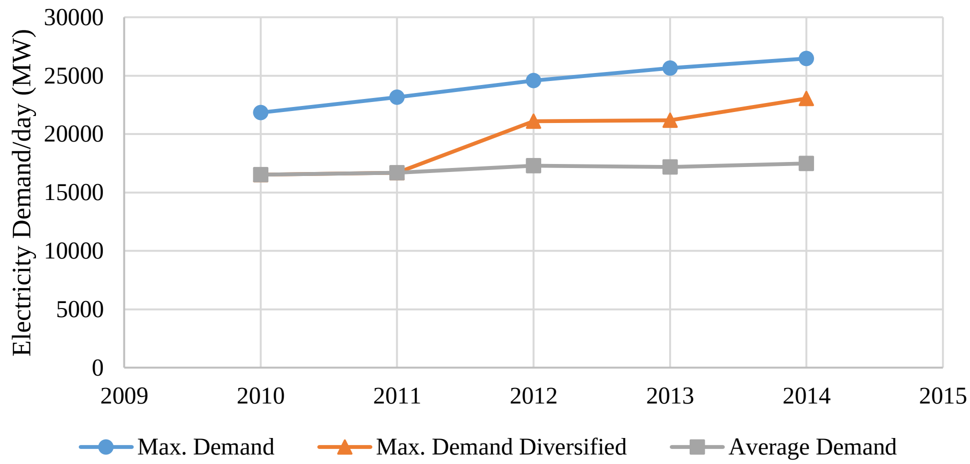

Figure 3.21 Electricity demand per day, 2009-2014

The increasing trend of demand is due to factors including increasing population, improving lifestyles, urbanization and industrialization etc. A more detailed analysis of hourly demand in summer and winter time can show a more comprehensive perspective on the overall demand trend. Figure 3.22 illustrates hourly demands in summer and winter, as well as weekdays and weekends. The data is taken from State of Industry Report 2014.

According to NEPRA's State of Industry Report, the peak demand for summer time is greater than the winter time because of extra power consumed by the air-conditioning units in both residential and commercial sectors. The summer time experiences greater demand at night times due to use of air-condition by the residential sector as people prefer sleeping in comfort in the hot summers. Less number of offices and other commercial buildings are centrally air-conditioned in Pakistan, which is why the mid-day demand is lesser. For the winters, the opposite is true. Demand increases at day time and is less at night, as majority of the heating systems are running on natural gas.

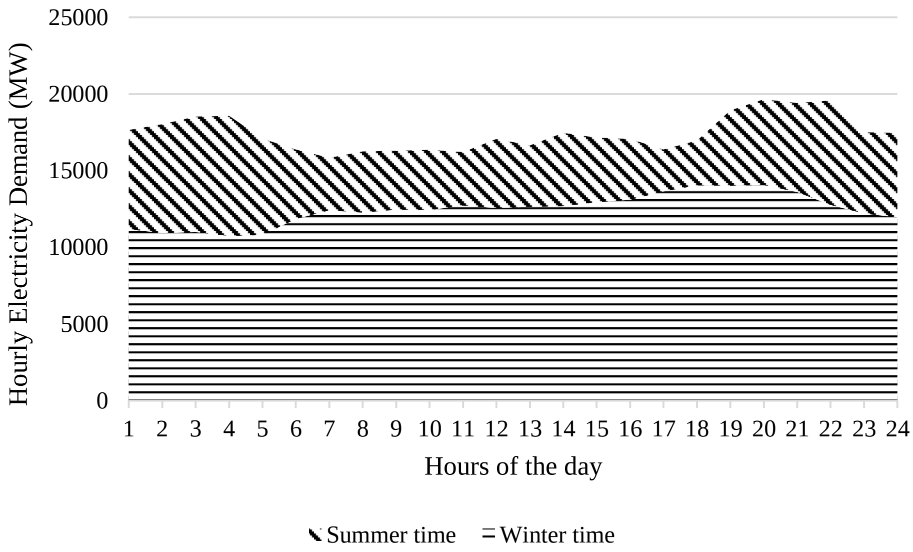

Figure 3.22 Hourly demand in summer and winter time, 2013

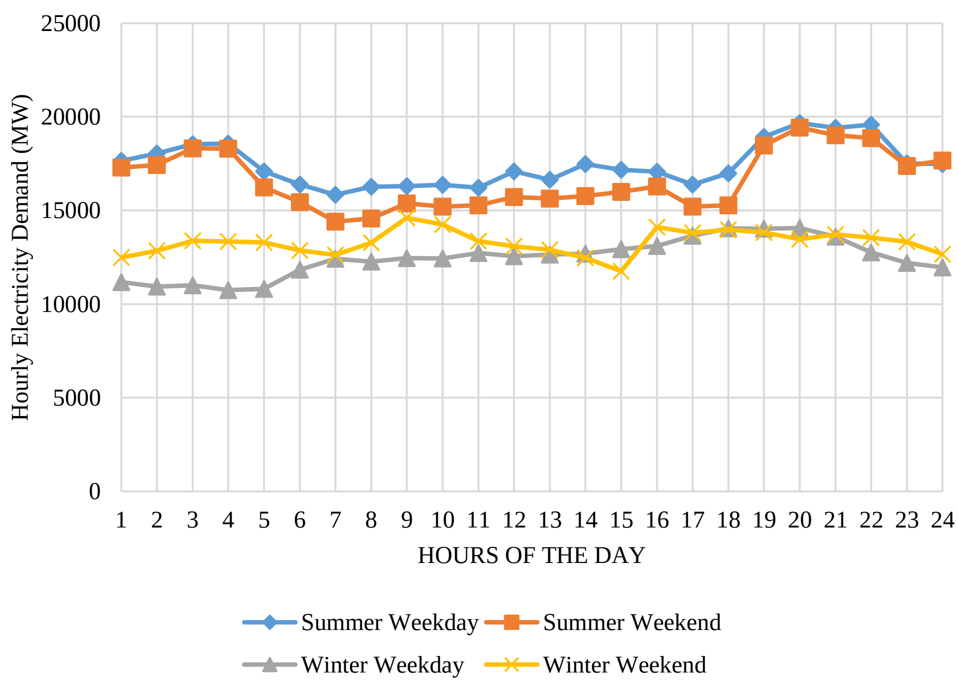

Figure 3.23 Weekday vs weekend hourly demand in summer and winter time

Figure 3.23 cuts down the weekday and weekend demand trend in summers and winters separately. The summertime weekend demand is lower due to the obvious fact that most of the commercial activities are closed, and the air-conditioning draws lesser power. In winters, however, there is no obvious difference in weekday and weekend consumption because of absence of air-condition requirement.

3.6.2 Demand and Supply Deficit

The major problem faced by the government as well as the people of Pakistan is the deficit in the demand and supply of electricity. When there is a difference between this demand and supply, the country has to face brownouts, and even blackouts on some occasions. Pakistan has been facing this problem for over a decade and a half now. The GOP, as well as the private sector, are struggling to overcome this problem, but apparently with fruitless outcomes (NEPRA 2014). Figure 3.24 shows the actual generation capacity vs the peak demand per day.

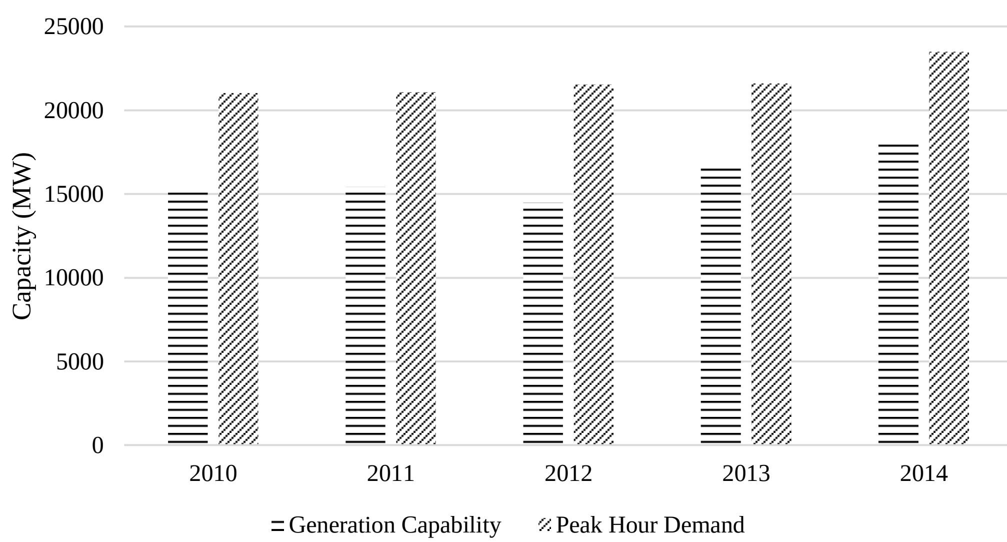

Figure 3.24 Generation capacity vs average demand per day (MW)

The generation capability is the maximum load a generator can take and it may differ from name plate capacity of the power plant. The reasons for this are (NEPRA 2014):

- Hydro capacity differs seasonably
- Not all power plants are fully functional
- For some power plants, the name plate capacity is higher than the actual operational capacity
- Underutilization of power plants, shown by the capacity factor in the previous sections
- Power losses, explained earlier, reduces the actual capacity

Due to these facts, the supply and demand is greatly unmatched. In 2014, the country faced a deficit of 5384 MW per day, which is about 23% of the peak hour demand. This means that on average, the country had to face 5.5 hours of black-out each day (23% of 24 hours is 5.5 hours).

Figure 3.25 below shows the deficit trend from 2010 to 2014. The country faced a major supply/demand deficit in the year 2012 due to lower generation capability (this is also backed by the fact that T&D losses were maximum in this period) (NEPRA 2014). Although, the gap is decreasing, but this is insufficient to curb the problem any time soon. Industries, agriculture sector and common lifestyle are greatly affected by lack of sufficient power.

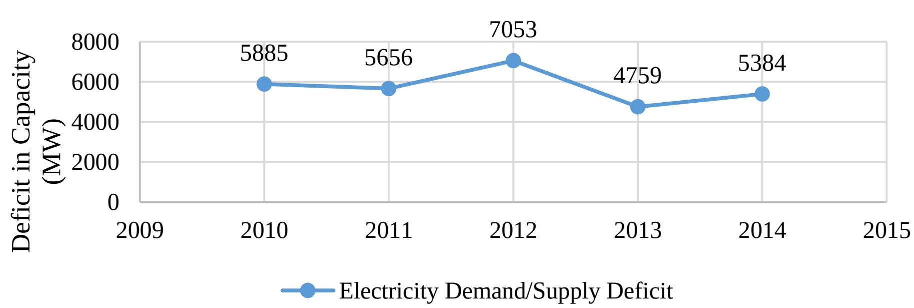

Figure 3.25 Electricity demand and supply deficit

3.6.3 Electricity Consumption

Electricity consumers in Pakistan are categorized as residential, commercial, industrial, agriculture, public lighting, and railway traction. The fact that Pakistan is a developing nation, the overall energy consumption is less than a developed country with the same population. Industries are sparse, and the structure of the commercial sector does not require a lot of energy. Even with this fact, the industries are suffering from power deficit, especially the smaller ones. Private business owners in the commercial sector are forced to cut down or close their setups. The agriculture output of the country is going down. The general population of Pakistan are fed-up of the power shortages, especially in summer time when the heat gets unbearable without an air-conditioner or a simple fan.

Figure 3.26 compares the energy generated with energy consumed (the difference is the total losses incurred in the system, which were discussed earlier).

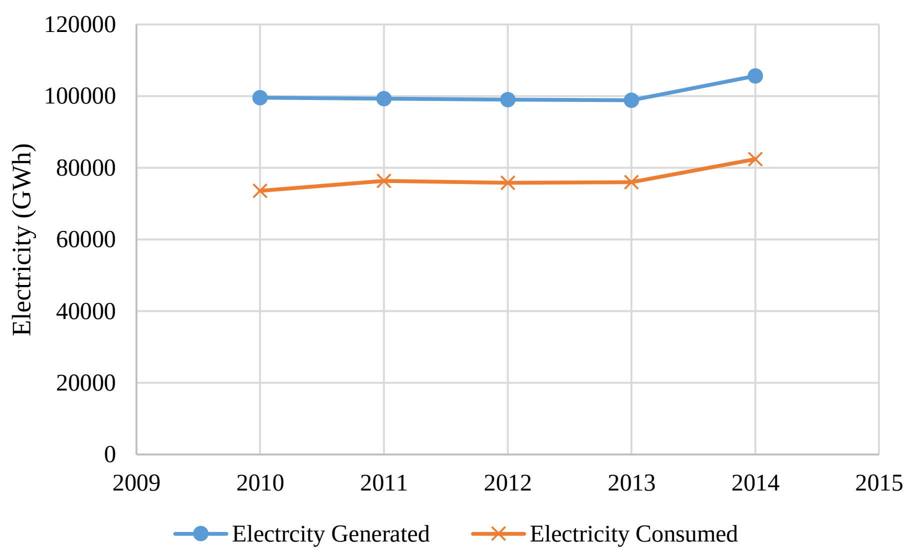

Figure 3.26 Electricity generated vs electricity consumed (GWh), 2010-2014

It can be seen that there has not been any significant growth in the electricity generation, and hence the consumption being a function of generation, it also saw no growth. Compared to an annual population growth of 1.49% (Indexmundi 2015), it is evident that the supply/demand deficit is increasing. However, in the above graph it can be seen that the year 2014 saw an improvement in the situation due to opening of a few new power plants as described earlier in the report. But this improvement is nowhere near to solving the shortage of electricity. The gap between the generation and consumption is due to all the combined losses, described in the T&D losses section.

A more detailed analysis can be done by showing the energy consumption per capita, as this indicator provides a survey in economic terms. It calculates the electricity available per capita in a region. It will be useful to compare this value for Pakistan with its neighbor, India and also Turkey. Figure 3.27 illustrates this comparison (tellmaps.com 2016). The comparison shows an unacceptable situation for Pakistan if it wants to pave its way towards development. India, being of the same cultural and national background, is doing much better, while Turkey is the best performer among the three with 6.6 times more consumption per capita than Pakistan in 2013. Pakistan is ranked 117 out of 141 country-wise, while India and Turkey are on 107 and 70 respectively in terms of per capita consumption of electric power (tellmaps 2016).

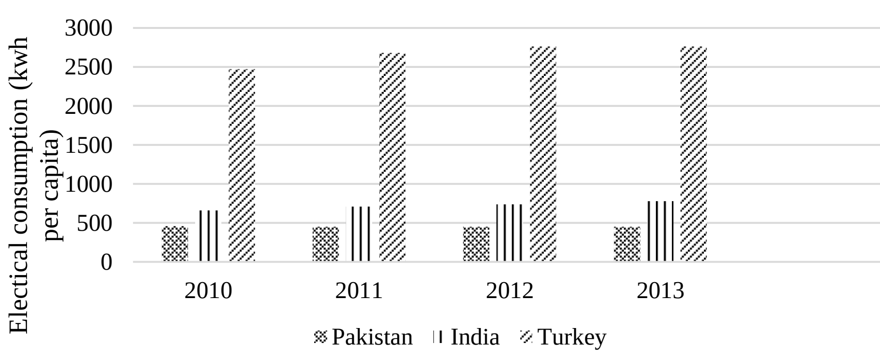

Figure 3.27 Per capita energy consumption Pakistan vs India vs Turkey, 2010-2013

Consumption Sector-wise

This section will identify the energy each sector draws from the grid. This analysis is useful in identifying the importance of various consumer sectors and their progress over the years. Figure 3.28 shows the sector-wise consumption.

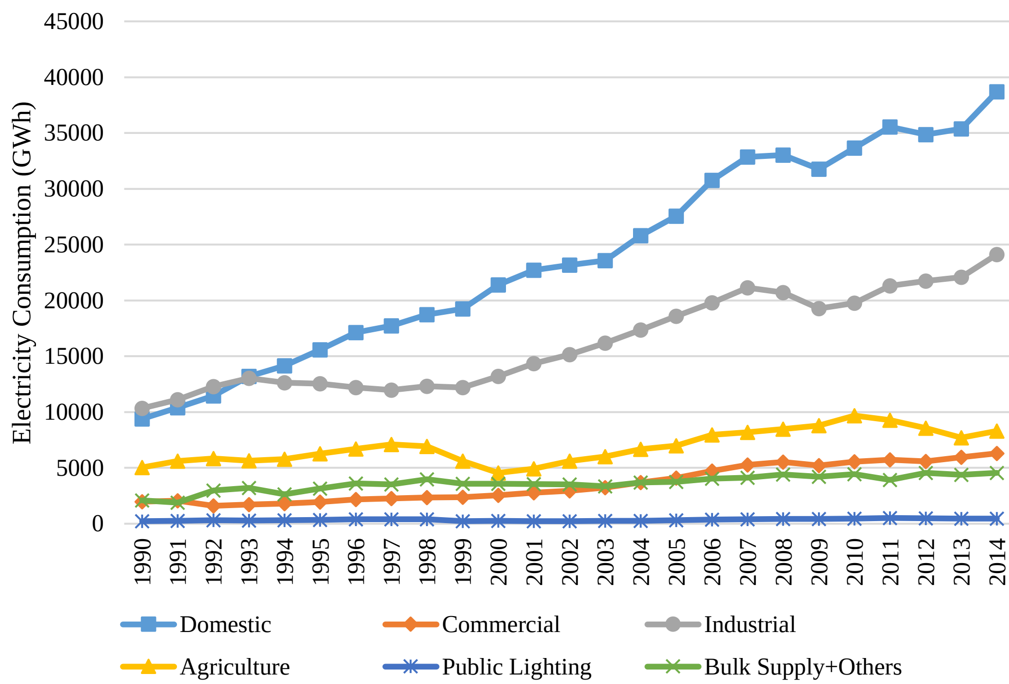

Figure 3.28 Sector-wise electricity consumption, 1990-2014

As seen in figure 3.28 and 3.29, the domestic sector is the highest consumer of the available energy making up approximately 47% of the total electricity, followed by industrial sector with a 29% consumption of total electricity. The domestic consumption has increased over the years at a steady rate, while the industrial sector has seen a decrease between the years 2008-2010. The increase in domestic consumption is explained by the increased use of electrical appliances now available at cheaper prices after Chinese manufacturers took over the market. Another reason of this increase in the rural electrification projects initiated by the public DISCOs in the recent years, especially in the areas under GEPCO, LESCO, FESCO and IESCO. The industrial sector is suffering due to bad economic conditions and power shortages. This is the reason why there is no significant rise in the consumption by this sector (NEPRA 2014).

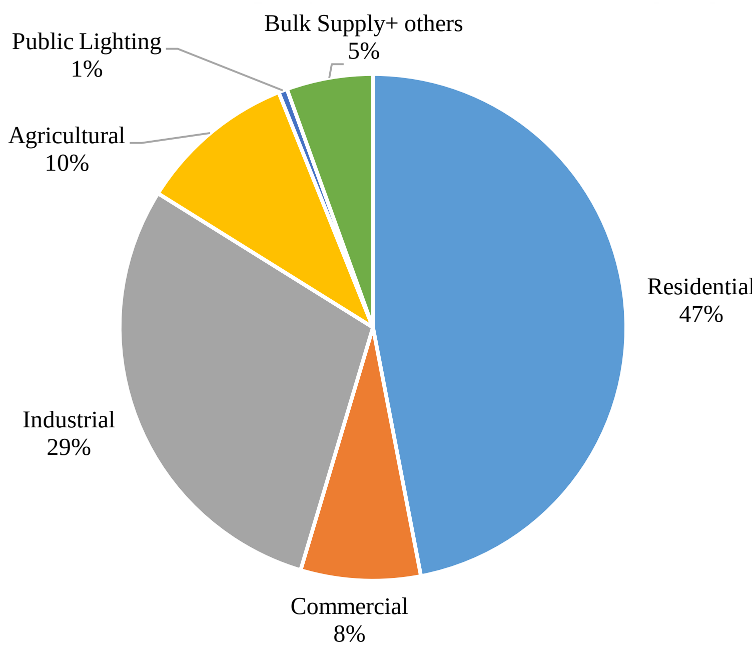

Figure 3.29 Sector-wise energy mix, 2014

Although the agriculture sector in Pakistan is of great importance, with bulk exports of cotton, wheat, rice and other products but this sector has seen no increase in consumption over the past two decades. Rauf et al. (2015) mentions in their report that power consumption by the agriculture sector has fallen by 7.1% in the recent years. This is explained by the lack of new investments made and continued use of traditional farming techniques.

Chapter 4

Electricity Consumption forecast with variation in Temperature using Multiple Regression

4.1 Introduction

According to Perwez et al. (2014) and Rauf et al. (2015), it is important to forecast the future energy and electricity needs so that an appropriate energy policy can be designed or upgraded. Frameworks of new projects can be decided according to the demand forecast. This can solve the issues of haphazard planning and energy shortages at any given time. In this study, monthly electricity forecast is performed through method of multiple regression. It is a statistical tool to analyze relationship between a dependent variable and one or more independent variables. There are a number of factors which determine the electricity consumption including population growth, urbanization, rural electrification, rising incomes, temperature and other socio-economic elements. The regression model uses these determinants and provides with an estimated value of the future demand. The seasonal variation index is used to divide the yearly electric consumption into monthly components for use in analysis.

General equation for multiple regression is given as:

$$\boldsymbol{\gamma = \beta + \alpha_1\omega_1 + \cdots + \alpha_n\omega_n}$$

Where,

γ is electricity consumption (independent variable)

β is constant (intercept)

α is slope for corresponding ω

ω are independent variables explaining the variance in γ

4.2 Data and Methodology

The determinants used in this study are explained in the following text.

1) Gross Domestic Product
2) Industrial Production Index (IPI)
3) Temperature
4) Population

In this thesis, the main focus on the varying consumption is the temperature. Increase in rest of the dependent variables produces general increase in electricity consumption. The dependent variables include GDP, IPI, temperature and population while consumption is the independent variable. All this data was put into the multiple regression model in excel and the results were achieved. Three scenarios are considered which are; i) Best: In this situation, the best conditions are considered from the past few years. The GDP and IPI have the highest values, whereas the population growth and temperature are minimum; ii) Good: In this situation, average is taken from the past years for all the independent variable values and inserted in the regression model; iii) Worst: In this situation, the worst conditions are considered from the past years. The GDP and IPI are the lowest, whereas the population growth and temperature are maximum.

4.3 Results

The results obtained shows a positive correlation between electricity consumption and monthly temperature (relative data is provided in table D.3 in Appendix D). The equation used in the regression model is:

$$Demand = \beta + (\alpha_1 \times Temperature) + (\alpha_2 \times Population) + (\alpha_3 \times IPI) + (\alpha_4 \times GDP)$$

Where,

β is the intercept value

α is the slope for corresponding independent variables

Tabular form of the data mentioned above is provided in tables D.1 and D.2 of Appendix D. The multiple R value for this model is 0.84, which means that the results are 84% accurate to the real value. Analysis is done for the years 2014-2020.

Figure 4.1 shows the relation between temperature and consumption for the first method for 2014. It can be seen in the figure that with increase in monthly average temperature, the consumption of electricity increases. This is analogous to the explanation in chapter 3, section 3.6.1, that increased consumption in summer season is due to use of air-conditioners, which draw a significant amount of electric power.

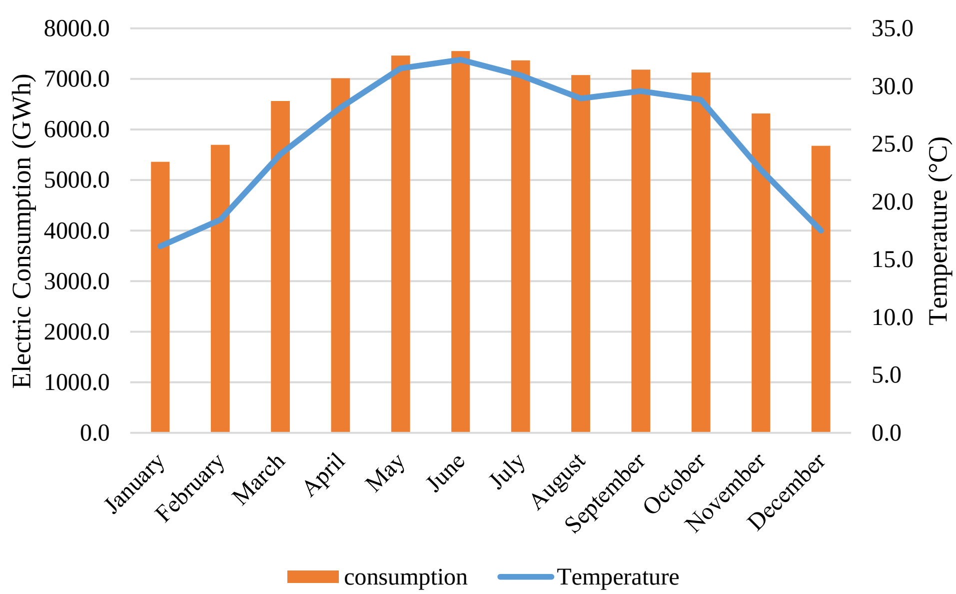

Figure 4.1 Dependence of electric consumption on temperature change, 2014

Consumption value obtained for 2014 are based on actual values of population, GDP and IPI, therefore it is higher than the consumption calculated for 2015, for which the above inputs are estimations based on good, bad and worst scenarios. It can be concluded that change in temperature has the highest effect on the consumption, compared to GDP growth, population and IPI. Yearly predicted consumptions are summarized in table 4.1. The overall result is satisfactory as the actual consumption in 2014 was 82419 GWh, which is very close to our predicted value of 80403.1 GWh. The increased use of cooling appliances (fans and air-conditioners) both commercially and domestically increases the demand of electricity by about 20% in summer time compared to winter time. In fact during summer time, the country faces the worst power outages, going as high as 10-12 hours per day (NEPRA 2014).

Year	Best (GWh)	Good (GWh)	Worst(GWh)
2015	79993.4	80163.7	80816
2016	80699.5	80902.3	81570.8
2017	81405.6	81640.8	82325.6
2018	82040	82324.7	83051.4
2019	82613.7	82962.2	83752.6
2020	83187.5	83599.6	84453.9

Table 4.1 Summary of predicted electricity consumption values

Although the model provides satisfactory results, but there are a number of limitations involved. The values of population, GDP and IPI are estimated and can differ in the coming years, which may vary the given results. The results obtained are based on the current situation of the electricity sector, which means that if the conditions are improved by successful application of the latest energy policies, the consumption rate will change significantly with change in supply. The other limitation is the consideration of electricity consumption and not the actual demand in order to eradicate the short supply. Another major limitation of the model is that it does not consider sector-wise consumption values, which is an important factor for future energy planning.

A number of previous studies have been conducted for forecasting of electricity demand. A previous study by Ali et al. (2013) performed a similar approach in forecasting monthly electricity consumption trends according to varying climatic changes. They used the seasonality index in order to slice the yearly electric consumption into monthly parts, and used the ARIMA method to deduce the results. They used the monthly temperature along with other socio-economic factors as inputs, similar to method in this report. Their result shows a similar trend of change in consumption with my thesis, indicating an increased consumption in summer time in the coming years. My method achieved a much closer value to the actual consumption of recent years, proving a good estimation of the input variables used.

Hussain et al. (2016) applied the Holt Winter and ARIMA models to forecast the consumption, and concluded that electricity consumption will continue to rise and further increase the supply-demand gap. According to them, the Holt Winter method provides comprehensive results compared to ARIMA. Table 4.2 compares the result of three studies with this one.

Year	**My results (GWh)**	**Ali, Jawed and Sharif (2013) results (GWh)**	**Perwez and Sohail (2014) results (GWh)**	**Hussain, Rahman and Memon (2015) results (GWh)**
2014	80403.1	68412.0	100000 (approx.)	84231.2
2015	79993.4	68448.0	100000(approx.)	86625.7

Table 4.2 Comparison of forecast results with previous studies

Perwez and Sohail (2014) drafted a comprehensive study for forecasting the future of electricity production and demand. They divided the case into three scenarios in terms of electricity production, namely Business-as-usual (BAU), New coal (NC) and Green future (GF). They then calculated the consumption according to these scenarios.

Although the studies use different methods and criteria for forecasting, the results of all can be combined to an estimation and frameworks on future policies can be drafted accordingly. Some studies estimate the value of future consumption, keeping in mind the supply and demand deficit which prevails, while other studies deduce the actual demand where there is no shortage of electricity. The results of my model can be used to draft a monthly structure of available generation capacity, for example during the summer, the government could operate most of the plants at full capacity and increase the mining or imports of fossil fuels.

Chapter 5

Problems, Recommendations and Conclusion

The whole energy sector of Pakistan is in a perilous state. The supply of power is far below the demand, and as a result, Pakistan has to face shortages. The root of the problem is a combined economic, political, technical and financial one. The government has already identified the problem and the solutions, but apparently has failed to implement any reasonable policy actions. A number of international organizations have issued reports to help end this war of energy shortage, including the Asian Development Bank (AEDB 2012). A report issued by this committee in 2010 argued that if immediate action is taken, the country could get rid of the problem in a few years (ESTF 2010). The 2013 elections delayed the implementation of the strategy proposed by the ADB, and is still shelved (Mills 2012). According to many studies, including Mills (2012), Ullah (2013), Rauf et al. (2015), the current situation of the country may prolong this energy deficit up to a decade, or more. This time frame is too long, keeping in view the downfall in domestic, commercial and industrial activities.

5.1 Problems

In a number of texts, including newspapers and government reports like the State of Industry 2014 by NEPRA, it is estimated that Pakistan is facing a deficit of around 5000 MW per day, mainly due to lack of investment and halfhearted reforms and policy implementation. In the past decade, the electricity demand has risen by 80%, while the supply is constantly failing to fulfill (Khan 2011). The demand is likely to increase, as one third of the population still does not have access to the national grid. As further electrification will take place, the demand will only increase.

One of the problems is lack of domestic energy sources to generate electricity. The national reserves of oil and gas are diminishing, with an estimated exhaustion by 2025-2030 (GOP 2013). These fossil fuels are the main source of electricity generation, which means that imports will eventually rise hence crippling the economy. It is estimated that energy imports will rise to 75% in 2025, compared to the current value of 25% (Javaid 2011). The government has long subsidized the fuel costs in order to help the general public. The government paid a sum of one trillion Pakistani rupees in subsidies (Pakistan Observer 2011). This obviously decreases the available budget in investing in new energy projects.

Both the public and private sectors are being badly inflicted by the energy deficits. The residential sector is facing long hours of load shedding, with up to 18-20 hours per day in some areas of Pakistan. The general public is fed up of this situation, and a number of rallies and riots have resulted in the past years due to this. Rauf et al. (2015) studies the effects of energy shortages and conclude that the industrial sector is no exception and no growth has been seen during the past decade. The textile industry, which is the backbone of the country's export, is greatly effected in terms of production and profits. The agriculture sector is suffering the same fate. The transport system is suffering from lack of availability of fuel. More than 1.6 million vehicles were running on compressed natural gas (CNG), with over 17000 CNG stations in place all over the country (Muslim 2016). Sadly, the CNG infrastructure has been completely shut down due to lack of natural gas supply and all the vehicle owners are forced to use fuel gasoline. This has greatly affected the common population. Yet again, this has led to a further increase in oil imports. The railway system has been forced to cut down the number of routes, and on some occasions, asked to completely shut down transport due to fuel shortages. As far as employment is concerned, an estimated 4.1 million jobs have been lost since 2008. This number amounts to 7.5% of the total workforce (Dawn News 2011). Due to all these factors, private investors are hesitant to put their assets on risk, hence creating a chain reaction of problems.

5.2 Reasons for Problematic Situation of Electricity sector

Khan (2011), Mills (2012) and Kessides (2013) identified the major reasons of the crisis which will be discussed and interpreted in the following text (the information is combined from all these studies).

- Circular debt
- Absence of adequate investments
- Reform and Governance issues
- Payment issues
- Security issues
- Tension between Provincial Governments
- Absence of local Industries and Engineering Expertise

Details of these factors are provided in Appendix G.

5.3 Recommended Solutions and Reforms

The problems are long standing and the previous governments failed to solve them. Recently, when the current government of Pakistan came in to power in 2013, it was aware of span of energy problems, but apparently has yet again failed to tackle it completely till now. In this thesis, the recommended solutions are divided into short term, medium term and long term and are discussed below. In view of previous studies, Khan (2011), Mills (2012) and Rauf et al. (2015) made similar suggestions. The following text is based on the studies made by these authors.

Short term

A regular power plant based on thermal generation takes three to five years to establish, where as an autoproducer takes as less as six to eight months. This is like a small portable plant which can be setup at any location or time. Although, the overall costs are higher than usual, but this technique helps balance the supply and demand deficit in a short time. The government can rent these autoproducers to fill the gap between demand and supply of electricity till a permanent solution can be applied. In 2009, the cabinet approved opening of fourteen RPPs, but according to the Asian Development Bank analysis, only eight were recommended to be setup. Finally, 1500 MW of capacity was installed in form of RPPs, but again due to lack of available capital, the administration could not handle this system and it has not proved to be a problem solver (Mills 2012).

Another major concerns are both the power and financial losses within the system. Undoubtedly, ending the circular dent is a tough job, but once achieved, it can solve the energy crisis. This will mean that more funds will be available for power generation, and the power plants would be able to operate at full capacity. As discussed earlier, subsidizing fuel costs is a heavy burden on the economy. These low domestic prices also abolishes the interest to exploit new resources, or invite foreign and local investments.

The revamping of the transmission and distribution system may also result as a problem solver. As discussed before, the power losses are as high as 20%, therefore rehabilitating the power system needs more attention. The GENCOs are performing below standard, and a huge energy loss is due to their inefficient running. New equipment and techniques should be applied by the authorities as this step does not seem to be a very complicated one. Besides this, the local population should be made aware of the importance of bill payment. Strict laws should be introduced against power theft and on-time bill payments. The higher officials should be urged to abide by the laws too (Rauf et al. 2015).

Medium Term

The medium solution mainly revolves around the need to establish a better energy policy. The government should aim for a well-drafted, well-improvised and a targeted policy for comprehensive results. Till now, the energy policy has completely failed to fulfill the purposes, with time to time amendments made with no success factor. The new energy policy should especially focus on energy efficiency, cost effectiveness, lucrative incentives to promote investments and better management practices. This could, in addition, promote international investments to a great deal (Mills 2012), (Khan 2011) and (Rauf et al. 2015).

Long Term

Pakistan's energy mix is too much dependent on the fossil fuel sources, of which the domestic resources are scarce. This mix should be diversified and spread evenly between all the available resources, such as hydro, nuclear, coal and renewables. The exhaustion of local fossil fuel resources and heavy reliance on oil imports does not point to the betterment of the energy situation. Although this is a colossal task, but once achieved, it may solve the crisis once and for all.

When gas reserves were discovered in 1950's, it was believed that they could last for a very long time. The whole energy structure was carved on the basis of gas as the primary fuel of the country, but unfortunately the truth has been revealed and gas reserves could finish by 2025 (Mills 2012). Although latest evidence shows further untapped gas reserves, it is difficult to exploit them due to security reasons discussed earlier in this report. For now, the main prospects in terms of gas are the import from the neighboring country Iran. The government has initiated the project and the completion is estimated to be in 2017 (Pakistan Today 2015).

Pakistan imports around 80% of its oil products (ADB 2009). Historically, this was a viable solution due to friendly cooperation with the Gulf States, but because of reasons like increasing power demand and lack of import budget, this no longer is a solution to fulfill power needs. The government should restructure a system into a non-oil dependent one. It should stop issuing new licenses to companies that are willing to produce power using oil or gas (Mills 2012).

Pakistan has not signed the Nuclear non-Proliferation Treaty, and due to constant terrorist threat, the nuclear generation program of Pakistan faces international sanctions. The government should express to the international organizations that it is more interested in generating power from nuclear resources other than for war purposes. China, however, is supportive of this endeavor and supplies uranium to the existing nuclear stations in Pakistan. Currently, new projects are under construction including CHASHMA III and KANUPP II. The government should invest more and appeal to other countries to help develop this sector. Not many countries of the world are lucky enough to possess this technology, and Pakistan should therefore exploit this fact to the fullest (Mills 2012).

According to the geography of Pakistan, hydroelectricity should be the choice of fuel. With a potential of around 60,000 MW of which only 7117 MW is exploited, this could end the problem and the country could even export the excess power, with added benefits of almost costless production. Federal tensions, security issues and lack of huge capital are the reasons for the under development of this sector. The country should once again promote international interest in investing in hydro plants. The new 4,500 MW Diamer Bhasha dam could really release the pressure on the energy system. It is backed by a number of financers, the leading one being the ADB (Mills 2012). The government should continue to pay full attention to this project and initiate it as soon as possible (Mills 2012).

It is estimated the Pakistan can produce 100,000 MW for three hundred years using its coal reserves. But shockingly, there is only one coal power plant in operation. The reason for such low utilization is the fossil fuel dominant energy structure. After the realization of ending gas reserves and infeasibility of oil imports, the government is paying attention to harvesting the coal reserves. Although the Thar coal mine, the largest in Pakistan, provides a low quality coal, it may be the leading factor resolve energy shortages. A number of new projects are pipelined aimed for electricity generation but again they are facing obstacles due to financing, environmental laws and failed governance (Mills 2012).

Pakistan is blessed with plentiful sunshine and wind. The estimated statistics of potential are (Rauf et al. 2015):

- Wind: 50,000 MW (theoretical)
- Solar: 20,000 MW (theoretical)
- Waste and biogas: 3000 MW

Currently, there is almost no progress in this field, despite the existence of the Alternate Energy Development Board (AEDB). Use of renewable energy can be seen in private homes and offices, but recently a number of projects are pipelined for development, including the huge Quaid-e-Azam solar park (Mills 2012).

Apart from these measures, Pakistan needs to plan out a proper structure to secure the long term energy prospects. Key projects like TAPI (pipeline running from Turkmenistan, Afghanistan, Pakistan and India) and IP (Iran pipeline) show be seriously perused by the government through bilateral talks and agreements with other governments (Mahmood et al. 2014). Swift development of the deep sea Gwadar Port should be launched to improve trade. The government should comply with its key partners for energy trading, including China, USA, Iran, Russia, Saudi Arabia, Turkey, Iran and India in order to develop an influx of resources and improve the overall economic standing of the country.

In conclusion, the renewable approach seems fruitful, but for developing countries like Pakistan, it is economically difficult to produce electricity through such expensive means. A single field of wind turbines may cost millions of dollars for a small amount of installed capacity. After completing the research needed for this thesis, according to my own speculation, coal seems to be the best solution for solving the electricity shortages. New processing technologies can even utilize the low coal quality, which is found in Pakistan, to produce electricity with low pollution contents. Future studies should focus on modelling and integrating coal resources in the electricity mix of Pakistan, and should provide practical models to the government and other energy agencies so that work in this field can be started immediately.

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Appendices

All the data used for the analysis in this report is provided in the appendices in tabular form. Appendix A provides energy budget statistics. Appendix B provides detailed information about the major power plants in Pakistan. Appendix C provides all the electricity generation data used in Chapter 3 of the study. Appendix D contains data and statistics used in the multiple regression model.

Appendix A

Table A.1 Energy budget of 2013 (Energy Information Administration 2015)

2013 *ktoe*	**Coal**	**Crude oil**	**Oil products**	**Natural gas**	**Nuclear**	**Hydro**	**Solar**	**Wind**	**Biofuels/ waste**	**Electricity**	**Total**
Production(+)	1292	3791		25755	1239	2681	(s)	(s)	30398		**65156**
Imports(+)	2557	7819	11651							34	**22061**
Exports(-)			-814								**-841**
Bunker(-)			-294								**-294**
Stock changes(+/-)			-75	8							**-68**
Statistical error(+/-)		-6		-23						65	**37**
Transfers(+/-)		-213	226								**13**
Total Supply (Net)	**3849**	**11391**	**10694**	**25740**	**1239**	**2681**	**(s)**	**(s)**	**30398**	**99**	**86078**

Transformations	**-152**	**-11391**	**2987**	**-7453**	**-1239**	**-2681**	**-s**	**-s**	**-606**	**6685**	**-13850**
Electricity plants	-38		-7895	-6389	-1239	-2681	-s	-s		8410	**-9832**
Oil refineries		-11391	11246								**-145**
Coal transformations	-114										**-114**
Other transformations									-606		**-606**
Energy industry own use			-364	-195						-292	**-852**
Losses				-869						-1433	**-2302**
Total final consumption	**3697**		**13681**	**18287**					**29793**	**6785**	**72241**

Sector wise total	**3697**		**13681**	**18287**					**29793**	**6785**	**72241**
Industry	**3697**		**1470**	**6668**					**3306**	**2004**	**17144**
Transport			**11073**	**2115**							**13188**
Others			**841**	**7019**					**26486**	**4781**	**39127**
Residential			353	6161					26486	3158	**36157**
Commercial and public Services			367	859						932	**2158**
Agriculture/forestry			35							691	**726**
Non-specified			86								**86**
Non-energy use			298	2484							**2782**
-of which chemical/petrochemical				2484							**2484**

Appendix B

Details of some major power plants in Pakistan (Power System Statistics 2014)

Thermal Power Plants (Gas, FO, HSD and Coal)

In Pakistan, there are a total of 53 thermal power plants scattered around the country. These power plants utilize fuels including coal, furnace oil (FO), high speed diesel (HSD) and natural gas. The total thermal installed capacity as of 2014 is 17209 MW The following table shows the number of thermal power plants owned by public and private sectors:

PUBLIC • PEPCO	12
PRIVATE • IPP’s	35
PRIVATE • KESC	6
Total	**53**

Table B.1 Thermal plants owned by public and private sectors

The largest plants under PEPCO system are the Jamshoro Power Station, Guddu Thermal Station and Thermal Power Station Muzaffargarh with capacities of 850 MW, 1655 MW and 1350 MW respectively. For all three plants, the main primary fuel type is natural gas. In the IPP domain, the most significant ones are KAPCO and HUBCO power plants with capacities of 1638 MW and 1292 MW respectively. For the KAPCO station, the primary fuel is natural gas while for the HUBCO station it is furnace oil. In KESC area, the main stations are the Bin Qasim Power Plant I & II with capacities of 1260 MW and 560 MW respectively and the primary fuel is natural gas. Keeping in view the above mentioned information, it is clear that natural gas is the most significant primary energy resource for thermal generation, which might put this sector into jeopardy owning to the fact that the main gas reserves of the country may finish in 10-15 years (The Express Tribune, 2012).

Hydro-electricity Power Plants

The geological nature of Pakistan beneficially allows for hydel generation, with five main rivers and a number of tributaries. The whole hydel setup is controlled and operated by WAPDA, with only a few projects owned by IPP's. There are 19 WAPDA owned (excluding ones with <1 MW capacity) and 4 privately owned dams. The total installed capacity of hydel generation is 7117 MW, with WAPDA owing to 98% of the total share. The three main hydel generation plants are:

1. Tarbela Dam

It is the world's largest fill-type dam, and second largest in respect of reservoir capacity which is 14.3 km^3 (Water Technology, 2015). It was constructed in 1976 and is located on river Indus close to Tarbela village. Its purpose includes irrigation, flood control and power generation. The total installed capacity is 3478 MW, and a venture known as 'Tarbela Fourth Extension Project' is underway to increase another 1410 MW of capacity (World Bank, 2013).

2. Mangla Dam

It is the 7^{th} largest dam in the world with a capacity of 9.12 km^3 (Butt, Waqas and Mahmood, 2010). It is located on the river Jhelum near the town of Mangla. The project was completed in 1967 with the help of British and USA based companies. This is a multi-purpose dam including irrigation and electricity generation. It has a generation capacity of 1000 MW and further addition of 310 MW capacity is planned (The Express Tribune, 2015).

3. Ghazi Barotha Dam

This is the most recent major hydel project which was commenced in 2003. It is situated on the river Indus near Attock district in Punjab. It has an installed capacity of 1450 MW.

According to many surveys, it is evident that there is great hydro-electricity generation potential in Pakistan and is under-utilized due to low government efforts and less incentives for private investors. The GOP does realize this potential and has initiated a number of projects for which feasibility reports are being made or has already been made. About 96 dams are already under construction, of which mostly are small projects (Wikipedia, 2015).

Nuclear Power Plants

Pakistan is the first Muslim country to own and operate nuclear power plants. There are currently three licensed power plants which are under the PAEC. The first nuclear plant was established in Karachi (KANUPP) in 1972 under the president-ship of Mr. Ayub Khan. Currently, a capacity of 787 MW serves the generation of electricity through nuclear reaction. This capacity is divided between the following three plants:

1. Chashma Nuclear Power Complex (CHASNUPP-I)

It is located in Chashma, Punjab and was constructed in May 2000. It is a pressurized water reactor with a generation capacity of 325 MW and an expected life of 40 years. It uses enriched uranium which is imported from China (NEPRA, 2003). It has a plant factor of 0.85-0.90 and an auxiliary consumption of 8% of rated capacity (NEPRA, 2003). It is connected to the 220 kV grid and provides electricity to NTDC.

2. Chashma Nuclear Power Complex (CHASNUPP II) Extension

The extension was constructed in 2011 with the help of China and was inaugurated by former president Mr. Yousaf Raza. It is pressurized light water nuclear power plant with a capacity of 325 MW and an expected life of 40 years. The primary fuel is slightly enriched uranium and is supplied by China. The power factor is given as 0.85. This plant also provides electricity to NTDC for transmission.

3. Karachi Nuclear Power Complex (KANUPP)

This was the first nuclear power plant constructed in Pakistan in 1972. It is located in Karachi, Sindh and provides power to the KESC transmission and distribution system. It is a pressurized heavy water reactor with a capacity of 137 MW. The primary fuel is natural uranium which is harvested locally.

To curb the energy supply-demand gap, the government has projected a nuclear installed capacity of 4400 MW by the year 2022 and 8800 MW by 2030 (Mustafa, 2012). This is the ‘Medium Term Development Framework’ developed in 2005. Extensions of the CHASNUPP and KANUPP are under construction and are expected to play a vital role in filling the energy deficits.

Coal Power Plants

Besides the massive coal reserves discovered in Pakistan, there is only one thermal power plant presently operating. It has a capacity of 150 MW (3x50 MW) but operates at a de-rated capacity of just 20 MW as only one of the units is functional, that even partially. Owing to this inefficient operation, the government has put this plant into the privatization list (Siddiqui, 2015).

11 new coal projects are under construction, mostly initiated by IPP’s. The main region of interest is the Thar Coal Mine. The largest project is the Gadani Energy Park, with a capacity of 6600 MW which China has provided (Wikipedia, 2015). Other projects are initiated by main stream companies like HUBCO, KESC and a number of China based companies.

Wind and Solar Power Plants

Development of wind and solar energy is at an infant stage in Pakistan. New laws have been passed to bring in investments in this sector. The first wind power plant is the Jhimpir Wind Power Plant, built by the Turkish company Zorlu Enerji, and has a generating capacity of 50 MW. Other projects include Jhimpir Wind FFCEL with a capacity of 50 MW, Three Gorges Wind Farm with a capacity of 50 MW and Foundation Wind Energy with a capacity of 100 MW. There are currently more than 20 projects in the pipeline, mostly assisted with companies from China and U.S, and generally have a capacity of 50-100 MW (Wikipedia, 2015).

Solar generation is comparatively less developed than wind. Although the Quaid-e-Azam Solar Park has a generating capacity of 1000 MW, but out of this only 100 MW is currently operational. The project was developed by Tebian Electric Apparatus Co. Ltd (China) and funded by Bank of Punjab. Once fully operational, it will be one of the biggest in the world. The expected year of completion is 2016. Regarding further development in solar energy harvesting, there are more than 10 projects in the pipeline with capacities ranging from 10-150 MW and for which the Letter of Interest has been issued by the GOP.

Appendix C

Table C.1 Installed capacity of power plants, 1980-2014 (NEPRA 2014)

	Hydro (MW)	Thermal (MW)	Nuclear (MW)	Wind (MW)	Solar (MW)	Total (MW)
1980	1567	1500				**3067**
1981	1847	1789				**3636**
1982	1847	1789				**3636**
1983	2547	1999				**4546**
1984	2547	2209	137			**4893**
1985	2897	2244	137			**5278**
1986	2897	2854	137			**5888**
1987	2897	3254	137			**6288**
1988	2897	3454	137			**6488**
1989	2897	4064	137			**7098**
1990	2897	4734	137			**7768**
1991	2897	5558	137			**8592**
1992	3329	5566	137			**9032**
1993	3761	5793	137			**9691**
1994	4725	6358	137			**11220**
1995	4825	7170	137			**12132**
1996	4825	7670	137			**12632**
1997	4825	9563	137			**14525**
1998	4825	10540	137			**15502**
1999	4825	10657	137			**15619**
2000	4825	11301	137			**16263**
2001	5039	11852	462			**17353**
2002	5039	12137	462			**17638**
2003	5039	12137	462			**17638**
2004	6493	12231	462			**19186**
2005	6493	12259	462			**19214**
2006	6493	12259	462			**19214**
2007	6474	12409	462			**19345**
2008	6555	12629	462			**19646**
2009	6555	13004	462			**20021**
2010	6555	14795	462			**21812**
2011	6645	16009	787			**23441**
2012	6729	16088	787	1		**23605**
2013	6947	16041	787	50	0.1	**23825.1**
2014	7117	17209	787	235	0.1	**25348.1**

Table C.2 Installed capacity of public and private thermal power plants, 1990-2014 (NEPRA 2014)

	Pubic Capacity (MW)	Private Capacity (MW)
1990	4083	790
1991	4705	1014
1992	4992	1014
1993	5202	1014
1994	5643	1214
1995	6053	1502
1996	6103	2471
1997	6410	3424
1998	6641	3789
1999	6641	4648
2000	6641	5526
2001	6641	5792
2002	6641	5792
2003	6641	5792
2004	6641	5792
2005	6641	5792
2006	4885	7548
2007	4885	7551
2008	4885	7482
2009	4885	8136
2010	4885	9910
2011	4885	11124
2012	4885	11204
2013	4885	11157
2014	5671	11538

Table C.3 Installed capacity of public and private hydro power plants, 1999-2014 (NEPRA 2014)

	Public Capacity (MW)	**Private Capacity (MW)**
1999	4809	0
2000	4809	30
2001	4993	30
2002	4993	30
2003	6443	30
2004	6443	30
2005	6443	30
2006	6443	30
2007	6443	30
2008	6443	111
2009	6443	129
2010	6515	129
2011	6515	129
2012	6611	129
2013	6733	214

Table C.4 Electricity generation, 1980-2014 (NEPRA 2014)

	Hydro (GWh)	Thermal (GWh)	Nuclear (GWh)	Wind (GWh)	Solar (GWh)	Imports (GWh)	Total (GWh)
1980	8718	6170					**14888**
1981	9046	6924					**15970**
1982	9526	8029					**17555**
1983	11366	8127					**19493**
1984	12825	8318	468				**21611**
1985	12248	10609	451				**23308**
1986	13807	11293	486				**25586**
1987	15255	12672	479				**28406**
1988	16694	15784	505				**32983**
1989	16981	17160	485				**34626**
1990	16930	20269	451				**37650**
1991	18302	22003	426				**40731**
1992	18652	26426	412				**45490**
1993	21116	27054	515				**48685**
1994	19441	30561	496				**50498**
1995	22863	30122	444				**53429**
1996	23210	33251	459				**56920**
1997	20862	36870	512				**58244**
1998	22064	35014	473				**57551**
1999	22452	37669	485				**60606**
2000	19288	43560	464				**63312**
2001	17259	46661	2024				**65944**
2002	19056	47834	2179				**69069**
2003	22350	48102	1895				**72347**
2004	27477	48714.2	2057.8			73	**78322**
2005	25671	53832	2712			109	**82324**
2006	30855	57178	2676			146	**90855**
2007	31942	60383	2372			171	**94868**
2008	28667	62654	2911			199	**94431**
2009	28183	62169	1559.6			227.4	**92139**
2010	28492	68337	2668			249	**99746**
2011	31990	64149	3130			269	**99538**
2012	28601	65478	4872	6	0.15	296	**99253.15**
2013	30524	64035	4181	32	0.15	375.1	**99147.25**
2014	32673	68196	4501	263	0.15	418.6	**106051.8**

Table C.5 Capacity factor of hydro, thermal and nuclear, 1980-2014 (NEPRA 2014)

	Hydro (%)	**Thermal (%)**	**Nuclear (%)**
1980	63.5	47.0	
1981	55.9	44.2	
1982	58.9	51.2	
1983	50.9	46.4	
1984	57.5	43.0	39.0
1985	48.3	54.0	37.6
1986	54.4	45.2	40.5
1987	60.1	44.5	39.9
1988	65.8	52.2	42.1
1989	66.9	48.2	40.4
1990	66.7	48.9	37.6
1991	72.1	45.2	35.5
1992	64.0	54.2	34.3
1993	64.1	53.3	42.9
1994	47.0	54.9	41.3
1995	54.1	48.0	37.0
1996	54.9	49.5	38.2
1997	49.4	44.0	42.7
1998	52.2	37.9	39.4
1999	53.1	40.4	40.4
2000	45.6	44.0	38.7
2001	39.1	44.9	50.0
2002	43.2	45.0	53.8
2003	50.6	45.2	46.8
2004	48.3	45.5	50.8
2005	45.1	50.1	67.0
2006	54.2	53.2	66.1
2007	56.3	55.5	58.6
2008	49.9	56.6	71.9
2009	49.1	54.6	38.5
2010	49.6	52.7	65.9
2011	55.0	45.7	45.4
2012	48.5	46.5	70.7
2013	50.2	45.6	60.6
2014	52.4	45.2	65.3
Average	54.2	48.1	47.7

Table C.6 Generation and installed capacity of power plants, 2010-2014 (NEPRA 2014)

Power Station	2010	2011	2012	2013	2014	2010	2011	2012	2013	2014
	Installed Capacity (MW)					Generation (GWh)				
Hydro (WAPDA)										
Tarbela Dam	3478	3478	3478	3478	3478	13905	15909	14057	14788	15178
Mangla Dam	1000	1000	1000	1000	1000	4772	5969	4666	4713	5872
Ghazi-Barotha Hydropower Project	1450	1450	1450	1450	1450	6796	7354	6979	7165	7008
Warsak Dam	243	243	243	243	243	1063	1036	991	1033	934
Chashma Barrage	184	184	184	184	184	1058	1001	1016	1106	1031
Dargai Hydropower Plant (Malakand-II)	20	20	20	20	20	111	83	84	97	90
Rasul Barrage Hydropower Project	22	22	22	22	22	91	96	65	49	53
Shadiwal Hydropower Plant	14	14	14	14	14	39	32	32	31	31
Chichonki Malian Hydropower Plant	13	13	13	13	13	30	32	32	43	37
Nandipur Hydropower Plant	14	14	14	14	14	39	43	41	50	42
Khan Khwar Hydropower Project	0	72	72	72	72	0	114	176	297	261
Jinnah hydropower project	0	0	0	96	96	0	0	0	202	297
Allai Khwar Hydropower Project	0	0	0	121	121	0	0	0	222	471
Gomal Zam Dam	0	0	0	0	17	0	0	0	1	26
Jabban Hydropower Plant (Malakand-I)	0	0	0	0	22	0	0	0	0	74
Duber Khwar	0	0	0	0	130	0	0	0	0	227
Others	6	6	6	6	6	23	16	17	21	26
Hydro (IPP)	6444	6516	6516	6733	6902	27927	31685	28156	29818	31658
Jagran-I Dam	30	30	30	30	30	135	0	66	107	105
Malakand-III Hydropower Project	81	81	81	81	81	430	292	337	395	389
Pehur (PEDO)	0	18	18	18	18	0	13	42	159	51
New Bong Escape Hydropower Plant	0	0	84	85	86	0	0	0	45	470
Sub-Total (HYDRO)	***6555***	***6645***	***6729***	***6947***	***7117***	***28492***	***31990***	***28601***	***30524***	***32673***
Thermal (WAPDA)										
Jamshoro Power Station	850	850	850	850	850	4281	2497	1445	1681	2982
Gas Turbine Power Station, Kotri	174	174	174	174	174	683	452	270	190	170
Guddu Thermal Station	1655	1655	1655	1655	2402	7212	5863	7258	6358	4399
Thermal Power Station Muzaffargarh	1350	1350	1350	1350	1350	6056	3629	3279	4477	5132
Gas Turbine Power Station, Faisalabad	244	244	244	244	244	638	144	40	30	130
Steam Power Station, Faisalabad	132	132	132	132	132	294	222	144	0	45
Gas Power Station, Multan	195	195	195	195	195	194	51	45	0	0
Lakhra coal power station	150	150	150	150	150	116	66	66	40	112
Gas Turbine Power Station, Shahdra	44	44	44	44	44	Isolated Generation				
WAPDA Quetta Thermal Power Station	35	35	35	35	35	120	94	105	97	85
Thermal Power Station, Pasni	17	17	17	17	0	0	0.8	0.24	0	0
Gas Turbine Power Station, Panjgur	39	39	39	39	0	0.06	2.06	1.51	0	0

Nandipur Power Project	0	0	0	0	95	0	0	0	0	0
Thermal (IPP)						19594	13020.8	12653.7	12873	13055
Lalpir Power Limited	362	362	362	362	362	2153	1105	1787	1643	2081
AES Pakgen Ltd.	365	365	365	365	365	2019	1311	1689	1936	2031
Altern Energy Limited	31	31	31	31	31	148	179	182	194	205
Fauji Kabirwala Power Company	157	157	157	157	157	1123	1088	1237	1107	1191
Habibullah Coastal Power (Pvt) Company	140	140	140	140	140	950	811	685	658	670
Hub Power Project	1292	1292	1292	1292	1292	8337	8114	7769	7673	7086
Japan Power Generation (Pvt) Limited	135	135	135	135	135	198	371	281	101	0
Kot Addu Power Company Limited	1638	1638	1638	1638	1638	7767	5688	6065	5521	6479
Kohinoor Energy	131	131	131	131	131	900	888	727	725	890
Rousch (Pakistan) Power Plant	450	450	450	450	450	3256	3039	2733	2536	2760
Saba Power Company Limited	134	134	134	134	134	628	244	116	85	138
Southern Electric Power Company Ltd	136	136	136	136	136	393	466	245	97	0
Liberty Power Project	235	235	235	235	235	1527	1333	1484	1438	943
Uch-I,II Power Plant	586	586	586	586	967	4119	4221	4278	3796	5071
Attock Gen Limited	165	165	165	165	165	1230	1203	1172	1255	1243
Atlas Power Limited	224	224	224	224	224	1212	1484	1067	1383	1519
Engro Powergen Qadirpur Limited	226	226	227	227	227	509	1562	1744	1693	1441
Saif Power Limited	225	225	225	225	225	317	1172	912	742	723
Orient Power Company Limited	225	225	225	225	225	280	1090	682	573	541
Nishat Power Limited	202	202	202	202	202	328	1473	1063	1276	1464
Nishat Chunian Limited	0	202	202	202	202	157	1452	1073	1283	1471
Sapphire Electric Company Limited	0	229	235	235	235	4	843	871	877	760
Halmore Power Gen Company Limited	0	225	225	225	225	0	209	570	374	504
Hubco Narowal Power Plant (HNPP)	0	225	225	225	225	0	463	1321	820	1562
Liberty Power Tech	0	202	202	202	202	0	997	1068	892	1520
Foundation Power Company Limited	35	182	183	183	183	35	403	1401	1380	1359
Davis Energen.	0	0	0	11	11	0	0	0	4	54
Gul Ahmed	136	128	128	128	128	608	745	452	432	582
Tapal Energy	126	124	124	124	124	638	793	481	684	798
Rental Power+other small	286	353	0	0	0	1108	113	1488	1280	1123
Thermal (KESC own)						38836	42747	43155	41178	45086
Bin Qasim Power Plant I	1260	1260	1260	1260	1260	5506	5068	4704	3722	3766
Bin Qasim Power Plant II	0	0	560	560	560	0	0	1140	3567	3693
Korangi Thermal Power Plant	250	125	125	125	125	222	271	163	0	0
Gas Thermal Power Station Korangi	108	108	108	97	97	531	676	595	327	393
Gas Thermal Power Station S.I.T.E	108	108	108	97	97	508	586	416	156	113
Korangi CCPP	220	220	220	220	220	1197	1225	1011	795	799
Other small producers	322	374	239	203	203	835	445	154	137	168

						7964	7826	8029	8567	8764
Sub-Total (THERMAL)	***14795***	***16009***	***16089***	***16042***	***17209***	***68337***	***64151.9***	***65479.8***	***64035***	***68196***
Nuclear Pakistan Atomic Energy Comission (PAEC)										
Chashma Nuclear Power Complex	325	650	650	650	650	2095	2930	4413	3640	4208
Karachi Nuclear Power Complex	137	137	137	137	137	573	200	459	541	293
Sub-Total (NUCLEAR)	***462***	***787***	***787***	***787***	***787***	***2668***	***3130***	***4872***	***4181***	***4501***
Renewables										
Jhimpir Wind Power Plant (Zorlu)	0	0	1	50	106	0	0	6	32	263
Jhimpir Wind Energy Project (FFCEL)	0	0	0	0	129	0	0	0	0	n.a
Quaid-e-Azam Solar Park	0	0	0.1	0.1	0.1	0	0	0.15	0.15	0.15
Sub-Total (Renewables)	***0***	***0***	***1.1***	***50.1***	***235.1***	***0***	***0***	***6.15***	***32.15***	***263.15***
GRAND-TOTAL	**21812**	**23441**	**23606**	**23826**	**25348**	**99497**	**99272**	**98959**	**98772**	**105633**
	Capacity (MW)					**Generation (GWh)**				
Average	**23606.66**					**100426.624**				

Table C.7 Capacity factor of power plants, 2010-2014 (NEPRA 2014)

	Power Station	2010	2011	2012	2013	2014
		Capacity Factor (%)				
	Hydro (WAPDA)					
1	Tarbela Dam	45.63912	52.21667	46.13802	48.53732	49.81738
2	Mangla Dam	54.47489	68.13927	53.26484	53.80137	67.03196
4	Ghazi-Barotha Hydropower Project	53.50339	57.89639	54.9441	56.40844	55.17241
5	Warsak Dam	49.93705	48.66866	46.55467	48.52773	43.87696
6	Chashma Barrage	65.63927	62.10294	63.03355	68.61723	63.96417
7	Dargai Hydropower Plant (Malakand-II)	63.35616	47.37443	47.94521	55.3653	51.36986
8	Rasul Barrage Hydropower Project	47.21876	49.8132	33.72769	25.42549	27.50104
9	Shadiwal Hydropower Plant	31.80039	26.09263	26.09263	25.27723	25.27723
10	Chichonki Malian Hydropower Plant	26.34352	28.09975	28.09975	37.75904	32.49034
11	Nandipur Hydropower Plant	31.80039	35.06197	33.43118	40.76973	34.24658
12	Khan Khwar Hydropower Project		18.07458	27.90462	47.08904	41.38128
13	Jinnah hydropower project				24.02017	35.31678
14	Allai Khwar Hydropower Project				20.94419	44.43564
15	Gomal Zam Dam					17.45904
16	Jabban Hydropower Plant (Malakand-I)					38.39768
17	Duber Khwar					19.93326
	Others	43.75951	30.4414	32.34399	39.95434	49.46728
	Hydro (IPP)	49.47259	55.50966	49.32712	50.55519	52.36058
18	Jagran-I Dam	51.36986	0	25.11416	40.71537	39.95434
19	Malakand-III Hydropower Project	60.60094	41.15226	47.49422	55.6683	54.82271
20	Pehur (PEDO)		8.244546	26.63623	100.8371	32.34399
21	New Bong Escape Hydropower Plant			0	6.043513	62.38717
	Sub-Total (HYDRO)	49.61879	54.956	48.52065	50.15798	52.40684
	Thermal (WAPDA)					
22	Jamshoro Power Station	57.49396	33.53478	19.40639	22.57588	40.04835
23	Gas Turbine Power Station, Kotri	44.80922	29.65412	17.71375	12.46523	11.1531
24	Guddu Thermal Station	49.74548	40.44062	50.06277	43.85493	20.90628
25	Thermal Power Station Muzaffargarh	51.2092	30.68662	27.72704	37.85726	43.39591
26	Gas Turbine Power Station, Faisalabad	29.84879	6.737031	1.871398	1.403548	6.082042
27	Steam Power Station, Faisalabad	25.42549	19.19884	12.4533	0	3.891656
28	Gas Power Station, Multan	11.35698	2.985599	2.634352	0	0
29	Lakhra coal power station	8.828006	5.022831	5.022831	3.04414	8.523592
30	Gas Turbine Power Station, Shahdra	-				
31	WAPDA Quetta Thermal Power Station	39.13894	30.65884	34.24658	31.63731	27.72342
32	Thermal Power Station, Pasni	0	0.537201	0.16116	0	
33	Gas Turbine Power Station, Panjgur	0.017562	0.602974	0.441986	0	

34	Nandipur Power Project					
	Thermal (IPP)					
35	Lalpir Power Limited	67.89399	34.84573	56.35233	51.81135	65.6235
36	AES Pakgen Ltd.	63.14506	41.00206	52.82417	60.5492	63.52036
37	Altern Energy Limited	54.49993	65.91545	67.02018	71.43909	75.48976
38	Fauji Kabirwala Power Company	81.65372	79.10886	89.9427	80.49036	86.59803
39	Habibullah Coastal Power (Pvt) Company	77.46249	66.12851	55.85453	53.65297	54.63144
40	Hub Power Project	73.66194	71.69162	68.64335	67.79514	62.60868
41	Japan Power Generation (Pvt) Limited	16.74277	31.37155	23.7612	8.540504	0
42	Kot Addu Power Company Limited	54.12966	39.64072	42.26811	38.47687	45.15335
43	Kohinoor Energy	78.42727	77.38157	63.35181	63.17752	77.55586
44	Rousch (Pakistan) Power Plant	82.59767	77.09285	69.33029	64.33283	70.01522
45	Saba Power Company Limited	53.49963	20.78648	9.882096	7.241191	11.75629
46	Southern Electric Power Company Ltd	32.98751	39.11496	20.56473	8.141955	0
47	Liberty Power Project	74.17662	64.75274	72.08783	69.8533	45.80783
48	Uch-I,II Power Plant	80.23984	82.22685	83.33723	73.94767	59.86363
49	Attock Gen Limited	85.09755	83.22956	81.08482	86.82718	85.99696
50	Atlas Power Limited	61.76614	75.62785	54.37663	70.48068	77.41153
51	Engro Powergen Qadirpur Limited	25.71019	78.89845	87.70342	85.1387	72.46595
52	Saif Power Limited	16.08321	59.4622	46.27093	37.64587	36.68189
53	Orient Power Company Limited	14.20599	55.30188	34.60173	29.07154	27.448
54	Nishat Power Limited	18.5361	83.24291	60.07279	72.10995	82.7343
55	Nishat Chunian Limited		82.05615	60.63791	72.50554	83.12989
56	Sapphire Electric Company Limited		42.02309	42.31031	42.60177	36.91829
57	Halmore Power Gen Company Limited		10.60375	28.91933	18.97514	25.57078
58	Hubco Narowal Power Plant (HNPP)		23.49061	67.02182	41.60325	79.24911
59	Liberty Power Tech		56.34296	60.35535	50.40915	85.899
60	Foundation Power Company Limited	11.41553	25.27723	87.39427	86.08429	84.77431
61	Davis Energen.				4.1511	56.03985
62	Gul Ahmed	51.03411	66.44192	40.31107	38.5274	51.90497
63	Tapal Energy	57.80242	73.00412	44.28119	62.96951	73.46443
	Rental Power+other small	44.22518	3.654262			
	Thermal (KESC own)					
64	Bin Qasim Power Plant I	49.88403	45.91578	42.61796	33.7211	34.11974
65	Bin Qasim Power Plant II			23.23875	72.71282	75.28131
66	Korangi Thermal Power Plant	10.13699	24.74886	14.88584	0	0
67	Gas Thermal Power Station Korangi	56.12633	71.45273	62.89109	38.48327	46.25053
68	Gas Thermal Power Station S.I.T.E	53.69525	61.93979	43.97091	18.35899	13.2985
69	Korangi CCPP	62.11083	63.56372	52.45953	41.25156	41.45911
	Other small producers	29.60237	13.58264	7.35561	7.704074	9.447331

	Sub-Total (THERMAL)	52.7275	45.74472	46.45943	45.56746	45.23756
	Nuclear Pakistan Atomic Energy Comission (PAEC)					
70	Chashma Nuclear Power Complex	73.58623	51.45767	77.50263	63.92694	73.90235
70	Karachi Nuclear Power Complex	47.74523	16.665	38.24618	45.07883	24.41423
	Sub-Total (NUCLEAR)	65.92342	45.40101	70.66892	60.64588	65.28752
	Renewables					
71	Jhimpir Wind Power Plant (Zorlu)			68.49315	7.305936	28.32343
72	Jhimpir Wind Energy Project (FFCEL)					0
73	Quaid-e-Azam Solar Park			17.12329	17.12329	17.12329
	Sub-Total (Renewables)			63.82316	7.325532	12.77752
	GRAND-TOTAL	52.07277	48.34437	47.85491	47.32356	47.57192
		Capacity Factor (%)				
	Average	48.63350722				

Table C.8 Cost of generation, 2010-2014 (NEPRA 2014)

	Power Station	2010	2011	2012	2013	2014
		Cost of Generation (Rs/kWh)				
	Hydro (WAPDA)					
1	Tarbela Dam	0.8	1.0	1.1	1.0	1.0
2	Mangla Dam	0.8	0.8	1.0	1.0	0.6
4	Ghazi-Barotha Hydropower Project	1.1	0.8	1.1	1.1	1.0
5	Warsak Dam	0.4	0.8	0.8	1.0	1.4
6	Chashma Barrage	1.4	0.8	1.6	1.7	1.8
7	Dargai Hydropower Plant (Malakand-II)	0.8	0.8	1.1	1.2	1.4
8	Rasul Barrage Hydropower Project	0.6	0.8	1.0	1.7	1.8
9	Shadiwal Hydropower Plant	0.9	0.8	1.4	1.5	1.8
10	Chichonki Malian Hydropower Plant	1.1	0.8	1.7	1.5	1.8
11	Nandipur Hydropower Plant	1.2	0.8	1.4	1.5	2.0
12	Khan Khwar Hydropower Project		0.8	1.9	2.8	2.4
13	Jinnah hydropower project			1.2	1.9	1.5
14	Allai Khwar Hydropower Project					1.3
15	Gomal Zam Dam					9.6
16	Jabban Hydropower Plant (Malakand-I)					
17	Duber Khwar					
	Others					
	Hydro (IPP)					
18	Jagran-I Dam					
19	Malakand-III Hydropower Project					
20	Pehur (PEDO)					
21	New Bong Escape Hydropower Plant					
	Sub-Total (HYDRO)					
	Thermal (WAPDA)					
22	Jamshoro Power Station	8.6	12.6	18.4	17.0	17.5
23	Gas Turbine Power Station, Kotri	5.0	5.8	5.2	7.4	7.1
24	Guddu Thermal Station	4.3	4.9	5.6	6.0	6.0
25	Thermal Power Station Muzaffargarh	11.4	14.2	18.4	18.1	18.4
26	Gas Turbine Power Station, Faisalabad	9.2	8.5	5.8	6.2	7.2
27	Steam Power Station, Faisalabad	13.4	16.0	22.4		8.5
28	Gas Power Station, Multan	18.3	22.7	23.2		
29	Lakhra coal power station	7.8	11.4	3.1	3.6	3.8
30	Gas Turbine Power Station, Shahdra					
31	WAPDA Quetta Thermal Power Station	5.7	6.5	7.7	9.2	10.7
32	Thermal Power Station, Pasni		42.1	97.6		
33	Gas Turbine Power Station, Panjgur	461.0	39.5	34.1		

34	Nandipur Power Project					
	Thermal (IPP)					
35	Lalpir Power Limited	12.0	15.7	18.8	19.0	18.9
36	AES Pakgen Ltd.	12.9	15.1	19.0	18.6	19.3
37	Altern Energy Limited	5.4	5.5	6.3	7.5	7.6
38	Fauji Kabirwala Power Company	5.7	5.7	5.2	5.7	5.5
39	Habibullah Coastal Power (Pvt) Company	4.4	4.9	6.3	7.5	7.4
40	Hub Power Project	11.9	15.0	18.7	19.4	18.9
41	Japan Power Generation (Pvt) Limited	12.4	12.9	17.6	n/a	n/a
42	Kot Addu Power Company Limited	12.6	15.2	19.0	19.8	20.0
43	Kohinoor Energy	10.6	12.3	16.7	15.9	17.0
44	Rousch (Pakistan) Power Plant	4.9	5.0	6.1	5.2	5.9
45	Saba Power Company Limited	12.2	17.4	25.1	25.3	24.0
46	Southern Electric Power Company Ltd	12.6	14.1	19.7	17.2	n/a
47	Liberty Power Project	8.4	10.3	13.3	12.3	22.5
48	Uch-I,II Power Plant	5.0	5.1	5.0	5.7	5.9
49	Attock Gen Limited		14.4	18.1	17.3	17.7
50	Atlas Power Limited		14.8	18.2	18.0	18.5
51	Engro Powergen Qadirpur Limited	n/a	4.6	5.8	6.7	7.1
52	Saif Power Limited	n/a	7.3	16.5	17.2	21.3
53	Orient Power Company Limited	n/a	6.2	14.3	16.3	18.8
54	Nishat Power Limited	n/a	13.8	18.6	18.9	18.3
55	Nishat Chunian Limited		14.4	19.0	19.0	18.4
56	Sapphire Electric Company Limited		6.5	16.6	18.1	20.6
57	Halmore Power Gen Company Limited			11.5	18.4	19.8
58	Hubco Narowal Power Plant (HNPP)		13.3	17.2	22.2	18.5
59	Liberty Power Tech		13.1	19.3	18.0	18.5
60	Foundation Power Company Limited		4.3	6.1	7.1	7.5
61	Davis Energen.	n/a	n/a	n/a	n/a	n/a
62	Gul Ahmed	11.6	13.2	15.8	15.6	15.8
63	Tapal Energy	11.7	13.3	15.1	15.5	15.7
	Rental Power+other small					
	Thermal (KESC own)					
64	Bin Qasim Power Plant I	5.2	8.0	9.3	12.5	12.5
65	Bin Qasim Power Plant II			4.4	4.3	4.5
66	Korangi Thermal Power Plant	4.4	5.0	5.6		
67	Gas Thermal Power Station Korangi	4.3	7.0	4.6	5.1	5.1
68	Gas Thermal Power Station S.I.T.E	4.5	5.4	4.4	5.5	5.4
69	Korangi CCPP	3.3	3.3	3.9	4.3	4.9
	Other small producers					

Table C.9 Technical specification of thermal plants

No.	Station	Location	Capacity (MW)	Fuel Type	Plant Type	Plant Units	Commencement date
	Water and Power Development Authority (WAPDA)						
1	Jamshoro Power Station	Jamshoro District, Sindh	850	gas/oil	Oil and Gas Fired Thermal Plant	1x250MW 3x200MW	January, 1990
2	Gas Turbine Power Station, Kotri	Kotri, Sindh	174	gas	Combined Cycle Gas Turbine	2x15MW 4x25MW 1x44MW	December, 1969
3	Guddu Thermal Station	Guddu, Kashmore, Sindh	1,655	gas/oil	Combined Cycle Gas Turbine	6x100MW 2x110MW 2x126MW 1x143MW 2x210MW	March, 1974
4	Thermal Power Station Muzaffargarh	Muzaffargarh, Punjab	1350	gas	Sub-critical Thermal	2x200MW 3x210MW 1x320MW	September, 1993
5	Gas Turbine Power Station, Faisalabad	Faisalabad, Punjab	244	gas	Open Cycle Power Plant	8x25MW 1x44MW	March, 1975
6	Steam Power Station, Faisalabad	Faisalabad, Punjab	132	gas	Steam Turbine/Heat recovery Plant	2x66MW	June, 1967
7	Gas Power Station, Multan	Multan, Punjab	195	gas	Combined Cycle Gas Turbine	3x65MW	June, 1963
8	Gas Turbine Power Station, Shahdra	Shahdra District, Lahore, Punjab	59	gas	Sub-critical Thermal	3x19.6MW	May, 1969
9	WAPDA Quetta Thermal Power Station	Quetta, Balochistan	35	gas	Open Cycle Gas Turbine	1x35MW	November, 1994
10	Thermal Power Station, Pasni	Pasni, Gawadar District, Balochistan	17	oil	Fire Oil Fired Plant	1x17	June, 1993
11	Gas Turbine Power Station, Panjgur	Panjgur District, Balochistan	39	gas	Gas Fired Plant	1x39MW	February, 1977
12	Nandipur Power Project	Gujranwala, Punjab	425	gas	Combined Cycle Gas Turbine	3x141.6MW	February, 2015
	Sub-Total		*5175*				
	Karachi Electric Supply Company (KESC)						
14	Bin Qasim Power Plant I	Karachi, Sindh	1,260	gas/oil	Sub-critical Steam Turbine	6x210MW	June, 1983
15	Bin Qasim Power Plant II	Karachi, Sindh	560	gas	Combined Cycle Gas Turbine	3x186.6MW	April, 2012
16	Korangi Thermal Power Plant	Korangi, Karachi, Sindh	125	gas/oil	Combined Cycle Gas Turbine	4x55MW 2x48MW	December, 2008
17	Gas Thermal Power Station Korangi	Korangi, Karachi, Sindh	97	gas	Combined Cycle Gas Turbine	4x20MW	July, 1996
18	Gas Thermal Power Station S.I.T.E	Karachi, Sindh	97	gas	Natural Gas Fired Plant	4x25MW	June, 2009

	Korangi CCPP	Karachi, Sindh	220	gas	Natural Gas Fire Plant		
	Others		203				
	Sub-Total		*2562*				
	Independent Power Producers (IPP's)						
19	Lalpir Power Limited	Mehmood Kot, Muzaffargarh, Punjab	362	oil	Sub-critical Steam Turbine	1x362MW	November, 1997
20	AES Pakgen Ltd.	Muzaffargarh, Punjab	365	oil	Fire Oil Fired Plant	1x365MW	Februaru, 1998
21	Altern Energy Limited	Fateh Jang, Punjab	31	gas	Fire Oil Fired Plant	4x7.25MW	September, 2004
25	Fauji Kabirwala Power Company	Kabirwala, Punjab	157	gas	Combined Cycle Gas Turbine	2x48.5MW 1x60MW	October, 1999
26	Habibullah Coastal Power (Pvt) Company	Quetta, Balochistan	140	gas	Natural Gas Fire Plant	3x37MW 1x29MW	September, 1999
27	Hub Power Project	Kot Addu, Muzaffar Garh, Punjab	1,292	oil	Sub-critical Steam Turbine	4x300MW	March, 1977
28	Japan Power Generation (Pvt) Limited	Raiwind, Punjab	135	oil	Fire Oil Fired Plant	24.5.65MW	March, 2000
29	Kot Addu Power Company Limited	Kot Addu, Muzaffargarh, Punjab	1,638	gas/oil	Combined Cycle Power Plant	16x100MW	February, 1987
30	Rousch (Pakistan) Power Plant	Kabirwala, Punjab	450	gas	Combined Cycle Power Plant	2x152MW 1x146MW	December, 1999
31	Saba Power Company Limited	Farooqabad, Sheikhupura, Punjab	134	oil	Sub-critical Steam Turbine	1x125MW	December, 1999
32	Southern Electric Power Company Limited	Raiwind, Lahore	136	oil	Fire Oil Fired Plant	5x27.2MW	July, 1999
33	Liberty Power Project	Daharki, Sindh	235	gas	Combined Cycle Power Plant	1x155MW 1x80MW	March, 2001
34	Uch-I,II Power Plant	Nasirabad District, Balochistan	967	gas/oil	Combined Cycle Power Plant	3x130MW 1x190MW 2x210MW	October 2000, April 2014
35	Attock Gen Limited	Rawalpindi, Punjab	164	oil	Fire Oil Fired Plant	2x82.5MW	March, 2009
36	Atlas Power Limited	Sheikhupura, Punjab	224	oil	Fire Oil Fired Plant	1x209MW 1x17MW	January, 2009
37	Engro Powergen Qadirpur Limited	Ghotki, Sindh	227	gas/oil	Combined Cycle Gas Turbine	1x127MW 1x100MW	February, 2010
38	Saif Power Limited	Sahiwal, Punjab	225	gas/oil	Combined Cycle Power Plant	3x75MW	June, 2010
39	Orient Power Company Limited	Balloki, Kasur District, Punjab	225	gas	Gas Fired Combine Cycle	2x76MW 1x77MW	January, 2010
40	Nishat Power Limited	Lahore, Punjab	202	oil	Fire Oil Fired Plant	11x18.1MW	July, 2011
41	Nishat Chunian Limited	Lahore, Punjab	202	oil	Combined Cycle Power Plant	11x17MW 1x13MW	June, 2010

42	Sapphire Electric Company Limited	Muridke, Sheikhupura District, Punjab	235	gas	Combined Cycle Gas Turbine Plant	2x76MW 1x82MW	February, 2009
43	Halmore Power Gen Company Limited	Sheikhupura, Punjab	225	gas	Combined Cycle Power Plant	3x75MW	February, 2009
44	Hubco Narowal Power Plant (HNPP)	Narowal, Punjab	225	oil	Combined Cycle Power Plant	11x18.5MW 1x21.5MW	April, 2011
45	Foundation Power Company Limited	Daharki, Sindh	183	gas/oil	Combined Cycle Power Plant	1x115MW 1x65MW	January, 2010
46	Liberty Power Tech	Faisalabad, Punjab	202	oil	Combined Cycle Power Plant	11x17MW 1x13MW	December, 2010
47	Gul Ahmad Energy Limited	Karachi, Sindh	128	oil	Fire Oil Fired Plant	8x17MW	November, 1997
48	Tapal Energy Limited	Karachi, Sindh	124	oil	Fire Oil Fired Plant	12x10.5MW	June, 1977
49	Kohinoor Energy Limited	Lahore, Punjab	131	oil	Fire Oil Fired Plant	8x15.8MW 1x6MW	June, 1997
49	Sitara Energy Limited	Jaranwala, Faisalabad, Punjab	85	gas/oil	Combined Cycle Power Plant	8x10.6MW	June, 1995
	Davis Energen.		11				
	Sub-Total		*9,060*				
		GRAND-TOTAL	**16,797**				

Appendix D

Table D.1 Industrial production index of Pakistan (GOP 2014)

Industrial Production Index	2009	2010	2011	2012	2013	2014
January	120.1	128.9	143.1	137.5	140.9	147.3
February	127.4	135.8	131.9	136.9	140.9	147.1
March	114.6	119	134.6	134	159.1	154.2
April	108.5	114.9	115.4	111.3	126.4	134.5
May	102.3	119	116	115.9	126.4	127.7
June	110.1	117.9	113.3	114	122.1	124.5
July	110.5	115.8	110.5	112.1	120.6	124.6
August	112.4	110.5	112.7	108.1	114.9	123.5
September	110.6	105.4	106.2	108.1	122	125.4
October	112.5	115.6	107.7	112.7	121.8	131.8
November	114.2	110	114.4	111.8	120.9	140.4
December	130.5	131.7	137.5	111.8	144.5	156

Table D.2 Regression model data (temperature, IPI, GDP, population, consumption)

Best	Temperature	Population	GDP Growth	IPI	Demand
2015January	15.5	185.0	4.4	147.3	5334.4
2015February	16.8	185.2	4.4	147.1	5524.6
2015March	24.1	185.5	4.4	159.1	6658.1
2015April	28.1	185.7	4.4	134.5	7071.7
2015May	31.5	185.9	4.4	127.7	7518.9
2015June	31.4	186.1	4.4	124.5	7487.9
2015July	30.9	186.4	4.4	124.6	7421.7
2015August	28.9	186.6	4.4	123.5	7132.2
2015September	28.9	186.8	4.4	125.4	7149.8
2015October	26.8	187.0	4.4	131.8	6896.4
2015November	21.5	187.2	4.4	140.4	6198.3
2015December	17.1	187.5	4.4	144.5	5599.2
2016January	15.5	187.7	4.4	147.3	5393.3
2016February	16.8	187.9	4.4	147.1	5583.4
2016March	24.1	188.1	4.4	159.1	6716.9
2016April	28.1	188.3	4.4	134.5	7130.5
2016May	31.5	188.6	4.4	127.7	7577.8
2016June	31.4	188.8	4.4	124.5	7546.8
2016July	30.9	189.0	4.4	124.6	7480.6
2016August	28.9	189.2	4.4	123.5	7191.0
2016September	28.9	189.5	4.4	125.4	7208.7
2016October	26.8	189.7	4.4	131.8	6955.2
2016November	21.5	189.9	4.4	140.4	6257.2
2016December	17.1	190.1	4.4	144.5	5658.1
2017January	15.5	190.3	4.4	147.3	5452.1
2017February	16.8	190.6	4.4	147.1	5642.3
2017March	24.1	190.8	4.4	159.1	6775.8
2017April	28.1	191.0	4.4	134.5	7189.4
2017May	31.5	191.2	4.4	127.7	7636.6
2017June	31.4	191.4	4.4	124.5	7605.6
2017July	30.9	191.7	4.4	124.6	7539.4
2017August	28.9	191.9	4.4	123.5	7249.9
2017September	28.9	192.1	4.4	125.4	7267.5
2017October	26.8	192.3	4.4	131.8	7014.0
2017November	21.5	192.6	4.4	140.4	6316.0
2017December	17.1	192.8	4.4	144.5	5716.9
2018January	15.5	193.0	4.4	147.3	5510.0
2018February	16.8	193.1	4.4	147.1	5699.3
2018March	24.1	193.3	4.4	159.1	6831.9

2018April	28.1	193.5	4.4	134.5	7244.6
2018May	31.5	193.7	4.4	127.7	7690.8
2018June	31.4	193.9	4.4	124.5	7659.0
2018July	30.9	194.0	4.4	124.6	7591.8
2018August	28.9	194.2	4.4	123.5	7301.3
2018September	28.9	194.4	4.4	125.4	7318.1
2018October	26.8	194.6	4.4	131.8	7063.7
2018November	21.5	194.8	4.4	140.4	6364.7
2018December	17.1	194.9	4.4	144.5	5764.7
2019January	15.5	195.1	4.4	147.3	5557.9
2019February	16.8	195.3	4.4	147.1	5747.1
2019March	24.1	195.5	4.4	159.1	6879.7
2019April	28.1	195.7	4.4	134.5	7292.4
2019May	31.5	195.8	4.4	127.7	7738.7
2019June	31.4	196.0	4.4	124.5	7706.8
2019July	30.9	196.2	4.4	124.6	7639.7
2019August	28.9	196.4	4.4	123.5	7349.2
2019September	28.9	196.6	4.4	125.4	7365.9
2019October	26.8	196.7	4.4	131.8	7111.5
2019November	21.5	196.9	4.4	140.4	6412.6
2019December	17.1	197.1	4.4	144.5	5812.5
2020January	15.5	197.3	4.4	147.3	5605.7
2020February	16.8	197.5	4.4	147.1	5794.9
2020March	24.1	197.6	4.4	159.1	6927.5
2020April	28.1	197.8	4.4	134.5	7340.2
2020May	31.5	198.0	4.4	127.7	7786.5
2020June	31.4	198.2	4.4	124.5	7754.6
2020July	30.9	198.4	4.4	124.6	7687.5
2020August	28.9	198.5	4.4	123.5	7397.0
2020September	28.9	198.7	4.4	125.4	7413.7
2020October	26.8	198.9	4.4	131.8	7159.3
2020November	21.5	199.1	4.4	140.4	6460.4
2020December	17.1	199.3	4.4	144.5	5860.3

Good	Temperature	Population	GDP Growth	IPI	Demand
2015January	16.4	185.0	2.8	136.3	5379.5
2015February	18.9	185.3	2.8	136.7	5739.1
2015March	24.6	185.5	2.8	135.9	6562.1
2015April	28.6	185.7	2.8	118.5	7023.3
2015May	31.7	186.0	2.8	117.9	7477.5
2015June	32.1	186.2	2.8	117.0	7533.0

2015July	31.0	186.4	2.8	115.7	7363.8
2015August	29.6	186.7	2.8	113.7	7151.7
2015September	29.4	186.9	2.8	113.0	7130.6
2015October	27.9	187.1	2.8	117.0	6947.4
2015November	22.9	187.3	2.8	118.6	6241.3
2015December	17.7	187.6	2.8	135.3	5614.3
2016January	16.4	187.8	2.8	136.3	5441.1
2016February	18.9	188.0	2.8	136.7	5800.7
2016March	24.6	188.3	2.8	135.9	6623.7
2016April	28.6	188.5	2.8	118.5	7084.8
2016May	31.7	188.7	2.8	117.9	7539.1
2016June	32.1	189.0	2.8	117.0	7594.5
2016July	31.0	189.2	2.8	115.7	7425.4
2016August	29.6	189.4	2.8	113.7	7213.2
2016September	29.4	189.7	2.8	113.0	7192.1
2016October	27.9	189.9	2.8	117.0	7009.0
2016November	22.9	190.1	2.8	118.6	6302.9
2016December	17.7	190.4	2.8	135.3	5675.8
2017January	16.4	190.6	2.8	136.3	5502.6
2017February	18.9	190.8	2.8	136.7	5862.2
2017March	24.6	191.1	2.8	135.9	6685.2
2017April	28.6	191.3	2.8	118.5	7146.4
2017May	31.7	191.5	2.8	117.9	7600.6
2017June	32.1	191.8	2.8	117.0	7656.1
2017July	31.0	192.0	2.8	115.7	7486.9
2017August	29.6	192.2	2.8	113.7	7274.8
2017September	29.4	192.4	2.8	113.0	7253.7
2017October	27.9	192.7	2.8	117.0	7070.5
2017November	22.9	192.9	2.8	118.6	6364.4
2017December	17.7	193.1	2.8	135.3	5737.4
2018January	16.4	193.3	2.8	136.3	5563.5
2018February	18.9	193.5	2.8	136.7	5922.4
2018March	24.6	193.7	2.8	135.9	6744.7
2018April	28.6	193.9	2.8	118.5	7205.1
2018May	31.7	194.1	2.8	117.9	7658.7
2018June	32.1	194.3	2.8	117.0	7713.4
2018July	31.0	194.5	2.8	115.7	7543.6
2018August	29.6	194.7	2.8	113.7	7330.7
2018September	29.4	194.9	2.8	113.0	7308.9
2018October	27.9	195.1	2.8	117.0	7125.0
2018November	22.9	195.3	2.8	118.6	6418.2
2018December	17.7	195.5	2.8	135.3	5790.5
2019January	16.4	195.7	2.8	136.3	5616.6

2019February	18.9	195.9	2.8	136.7	5975.5
2019March	24.6	196.1	2.8	135.9	6797.8
2019April	28.6	196.3	2.8	118.5	7258.3
2019May	31.7	196.5	2.8	117.9	7711.8
2019June	32.1	196.7	2.8	117.0	7766.5
2019July	31.0	196.9	2.8	115.7	7596.7
2019August	29.6	197.1	2.8	113.7	7383.8
2019September	29.4	197.3	2.8	113.0	7362.0
2019October	27.9	197.5	2.8	117.0	7178.2
2019November	22.9	197.7	2.8	118.6	6471.4
2019December	17.7	197.9	2.8	135.3	5843.6
2020January	16.4	198.1	2.8	136.3	5669.7
2020February	18.9	198.3	2.8	136.7	6028.6
2020March	24.6	198.5	2.8	135.9	6850.9
2020April	28.6	198.7	2.8	118.5	7311.4
2020May	31.7	198.9	2.8	117.9	7764.9
2020June	32.1	199.1	2.8	117.0	7819.6
2020July	31.0	199.3	2.8	115.7	7649.8
2020August	29.6	199.5	2.8	113.7	7437.0
2020September	29.4	199.7	2.8	113.0	7415.1
2020October	27.9	199.9	2.8	117.0	7231.3
2020November	22.9	200.1	2.8	118.6	6524.5
2020December	17.7	200.3	2.8	135.3	5896.8

Worst	Temperature	Population	GDP Growth	IPI	Demand
2015January	18.1	185.0	1.6	120.1	5504.4
2015February	20.4	185.3	1.6	127.4	5889.1
2015March	26.8	185.5	1.6	114.6	6722.6
2015April	30.1	185.7	1.6	108.5	7162.7
2015May	32.4	186.0	1.6	102.3	7464.4
2015June	32.4	186.2	1.6	110.1	7512.3
2015July	31.1	186.5	1.6	110.5	7333.4
2015August	30.3	186.7	1.6	108.1	7212.4
2015September	29.6	186.9	1.6	105.4	7097.2
2015October	28.8	187.2	1.6	107.7	7007.8
2015November	24.4	187.4	1.6	110.0	6395.4
2015December	18.2	187.6	1.6	111.8	5514.1
2016January	18.1	187.9	1.6	120.1	5567.3
2016February	20.4	188.1	1.6	127.4	5952.0
2016March	26.8	188.4	1.6	114.6	6785.5
2016April	30.1	188.6	1.6	108.5	7225.6

2016May	32.4	188.8	1.6	102.3	7527.3
2016June	32.4	189.1	1.6	110.1	7575.2
2016July	31.1	189.3	1.6	110.5	7396.3
2016August	30.3	189.5	1.6	108.1	7275.3
2016September	29.6	189.8	1.6	105.4	7160.1
2016October	28.8	190.0	1.6	107.7	7070.7
2016November	24.4	190.2	1.6	110.0	6458.3
2016December	18.2	190.5	1.6	111.8	5577.0
2017January	18.1	190.7	1.6	120.1	5630.2
2017February	20.4	191.0	1.6	127.4	6014.9
2017March	26.8	191.2	1.6	114.6	6848.4
2017April	30.1	191.4	1.6	108.5	7288.5
2017May	32.4	191.7	1.6	102.3	7590.2
2017June	32.4	191.9	1.6	110.1	7638.1
2017July	31.1	192.1	1.6	110.5	7459.2
2017August	30.3	192.4	1.6	108.1	7338.2
2017September	29.6	192.6	1.6	105.4	7223.0
2017October	28.8	192.9	1.6	107.7	7133.6
2017November	24.4	193.1	1.6	110.0	6521.2
2017December	18.2	193.3	1.6	111.8	5639.9
2018January	18.1	193.5	1.6	120.1	5692.7
2018February	20.4	193.8	1.6	127.4	6077.1
2018March	26.8	194.0	1.6	114.6	6910.2
2018April	30.1	194.2	1.6	108.5	7349.9
2018May	32.4	194.4	1.6	102.3	7651.3
2018June	32.4	194.6	1.6	110.1	7698.8
2018July	31.1	194.9	1.6	110.5	7519.5
2018August	30.3	195.1	1.6	108.1	7398.1
2018September	29.6	195.3	1.6	105.4	7282.6
2018October	28.8	195.5	1.6	107.7	7192.8
2018November	24.4	195.7	1.6	110.0	6580.0
2018December	18.2	196.0	1.6	111.8	5698.4
2019January	18.1	196.2	1.6	120.1	5751.2
2019February	20.4	196.4	1.6	127.4	6135.5
2019March	26.8	196.6	1.6	114.6	6968.6
2019April	30.1	196.8	1.6	108.5	7408.3
2019May	32.4	197.1	1.6	102.3	7709.7
2019June	32.4	197.3	1.6	110.1	7757.2
2019July	31.1	197.5	1.6	110.5	7578.0
2019August	30.3	197.7	1.6	108.1	7456.6
2019September	29.6	197.9	1.6	105.4	7341.0
2019October	28.8	198.2	1.6	107.7	7251.3
2019November	24.4	198.4	1.6	110.0	6638.4

2019December	18.2	198.6	1.6	111.8	5756.8
2020January	18.1	198.8	1.6	120.1	5809.6
2020February	20.4	199.0	1.6	127.4	6193.9
2020March	26.8	199.3	1.6	114.6	7027.1
2020April	30.1	199.5	1.6	108.5	7466.8
2020May	32.4	199.7	1.6	102.3	7768.1
2020June	32.4	199.9	1.6	110.1	7815.6
2020July	31.1	200.1	1.6	110.5	7636.4
2020August	30.3	200.4	1.6	108.1	7515.0
2020September	29.6	200.6	1.6	105.4	7399.5
2020October	28.8	200.8	1.6	107.7	7309.7
2020November	24.4	201.0	1.6	110.0	6696.9
2020December	18.2	201.2	1.6	111.8	5815.2

Table D.3 Summary output of regression model result

Regression Statistics	
Multiple R	0.917969943
R Square	0.842668816
Adjusted R Square	0.831226548
Standard Error	334.8706442
Observations	60

	df	*SS*	*MS*	*F*	*Significance F*
Regression	4	33033832.03	8258458.007	73.64526168	1.97581E-21
Residual	55	6167609.158	112138.3483		
Total	59	39201441.19			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-2008.193577	2286.794924	-0.878169509	0.383672011	-6591.033015	2574.645862	-6591.033015	2574.645862
Temperature	143.5435873	11.159031	12.86344552	3.21781E-18	121.1803894	165.9067851	121.1803894	165.9067851

Population	22.13505379	13.50896237	1.638545818	0.107016696	-4.937511771	49.20761936	-4.937511771	49.20761936
GDP Growth	7.153329009	85.04319787	0.084114064	0.933271162	-163.277048	177.5837061	-163.277048	177.5837061
IPI	6.726225331	5.46158312	1.231552314	0.223356273	-4.219031828	17.67148249	-4.219031828	17.67148249

Appendix E

Performance of the Distribution Companies in terms of SAIFI and SAIDI values

A continuous supply of electricity to the end consumers is the main aspect of performance indicator for any distribution company (NEPRA 2014). The distribution system in Pakistan is monitored by a number of indicators, but the two important ones will be discussed in this thesis. They are:

1. $System\ Average\ Interruption\ Frequency\ Index\ (SAIFI) = \frac{Total\ annual\ number\ of\ all\ Consumer\ Power\ Supply\ Interruptions}{Total\ number\ of\ consumers\ served\ by\ the\ distribution\ company\ in\ a\ given\ year}$

2. $System\ Average\ Interruption\ Duration\ Index\ (SAIDI) = \frac{Aggregate\ sum\ of\ all\ Consumer\ Supply\ Interruption\ durations\ in\ minutes}{Total\ number\ of\ consumers\ served\ by\ the\ distribution\ company\ in\ a\ given\ year}$

The SAFI and SAIDI indices are basically reliability indicators and uses the data of supply interruptions to customers to calculate the value. The lower the value, the better the performance of distribution. In North America, the SAIFI and SAIDI indices are 1.5 interruptions per customer and 4 minutes, respectively (Rouse and Kelly 2011). According to NEPRA's Performance Standard Rules 2005, SAIFI and SAIDI should not exceed the limit of 13 interruptions per customer and 14 minutes, respectively (NEPRA 2014).

According to figure 3.18, it is evident that only one of the DISCOs, i.e. IESCO, is working under the maximum limit of the SAIFI value according to NEPRA standards. The statistics of HESCO and SPECO are not shown due to unavailability of sufficient data. PESCO, MEPCO and QESCO comparatively have poorer performance compared to the others. The overall outcome shows an unsatisfactory performance of these distribution companies, and nothing has been done over the years to bring the SAIFI index to a reasonable value.

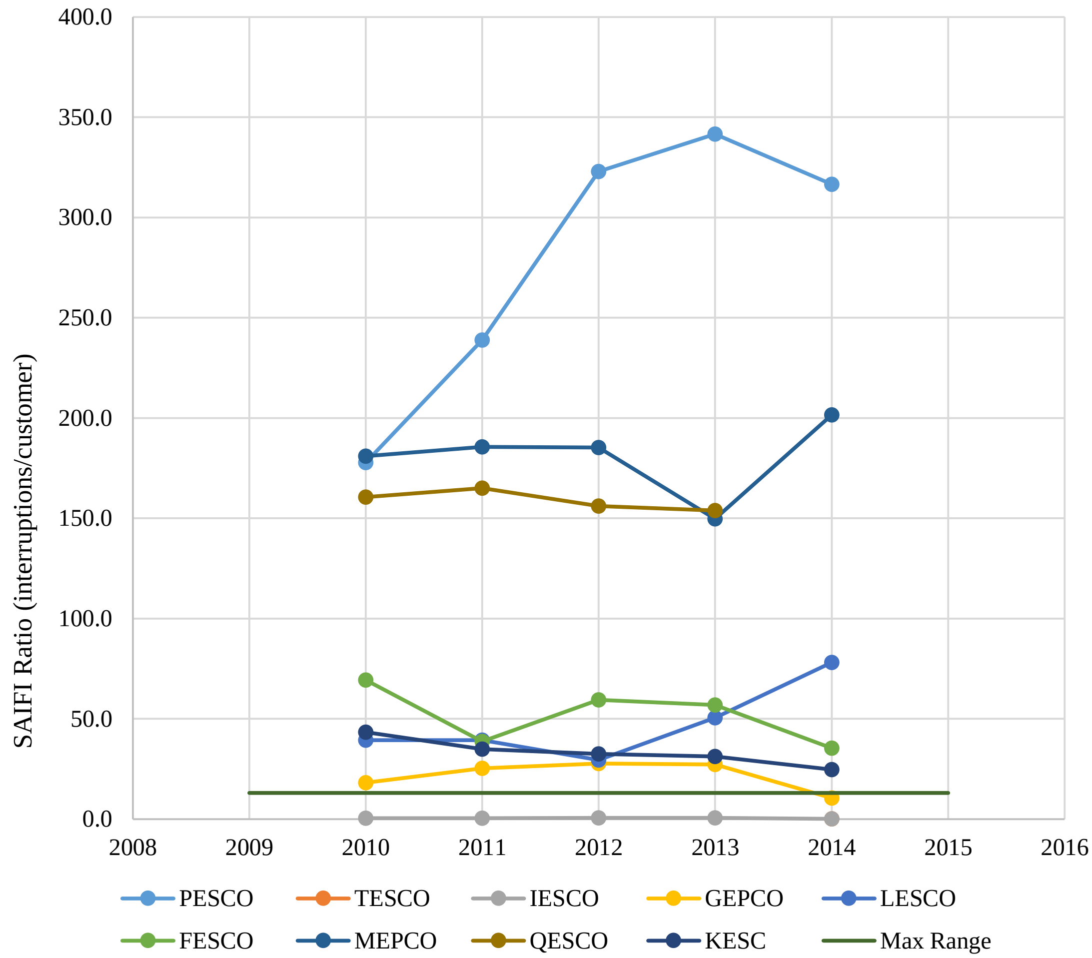

Figure 3.18 SAIFI performances of distribution companies, 2010-2014

The SAIDI values of distribution companies are shown in figure 3.19. They are way above the set value of 14 minutes. The worse performing ones are PESCO, QESCO and HESCO, while IESCO, LESCO and KESC are comparatively performing much better than the formers. The basic point to be noted here is that the companies based on major areas of Pakistan (i.e. Punjab region and Karachi which includes IESCO, LESCO, FESCO and KESC) are in a better state because of more resource input. The rest of the regions of Pakistan, in generally, are ignored in terms of infrastructural development and therefore the electricity distribution also suffers.

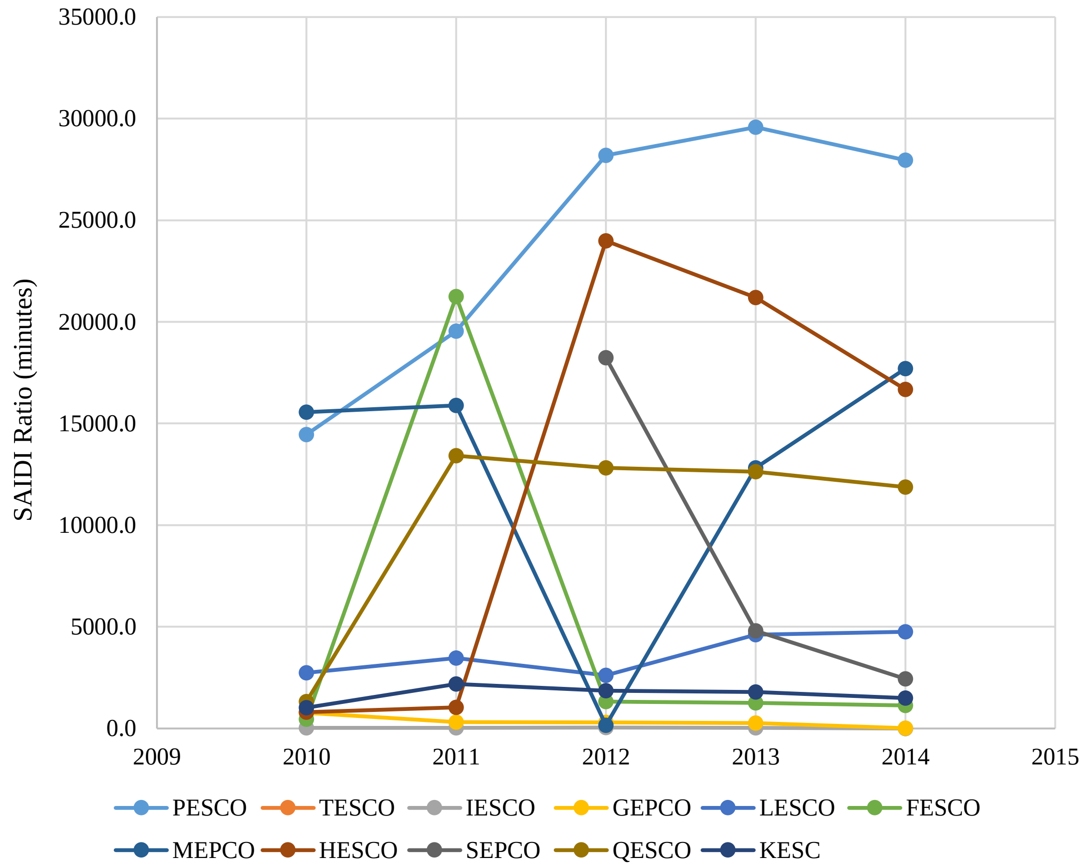

Figure 3.19 SAIDI performance of distribution companies, 2010-2014

The SAIFI and SAIDI performance indicators highlight the bad performance of the whole power infrastructure of Pakistan. According to Zakariya and Noureen (2016), the distribution system is one of the most important player in the power supply, and if this sector is performing poorly, the whole system can be under jeopardy. The high number of interruption and their duration points a lack of proper management, new investments and technical expertise faced by the companies. There hasn't been any bonus budgeting available to improve the distribution system, and the result is overall energy losses of more than 20%, as will be shown in the following section. The GOP and NEPRA identify this problem, and initiatives are being taken in order to privatize the distribution sector in order to achieve better performance and efficiency. Other than the statement made by the government, there is no further information available about this privatization action.

Not many studies are done regarding the performance of the distribution companies. Zakaria and Noureen (2016) performed cost efficiency analysis of distribution companies using stochastic frontier analysis (SFA) technique. They concluded that high cost of electricity are a result of inefficiencies in the distribution network. They performed the study for 8 DISCOs and their result shows that QESCO, FESCO and PESCO are the most under-performing ones, while LESCO and IESCO shows satisfactory functioning (with 79.3% and 76.5% efficiency rates respectively). These results are similar to the analysis done with SAIFI and SAIDI values in this report, showing that these indicators can be further worked with for a deeper analysis of the performance of the distribution network.

Appendix F

Distribution company-wise losses

This section will illustrate and compare the distribution losses company-wise. Figure 3.23 shows the percentages of losses incurred within the distribution companies of Pakistan.

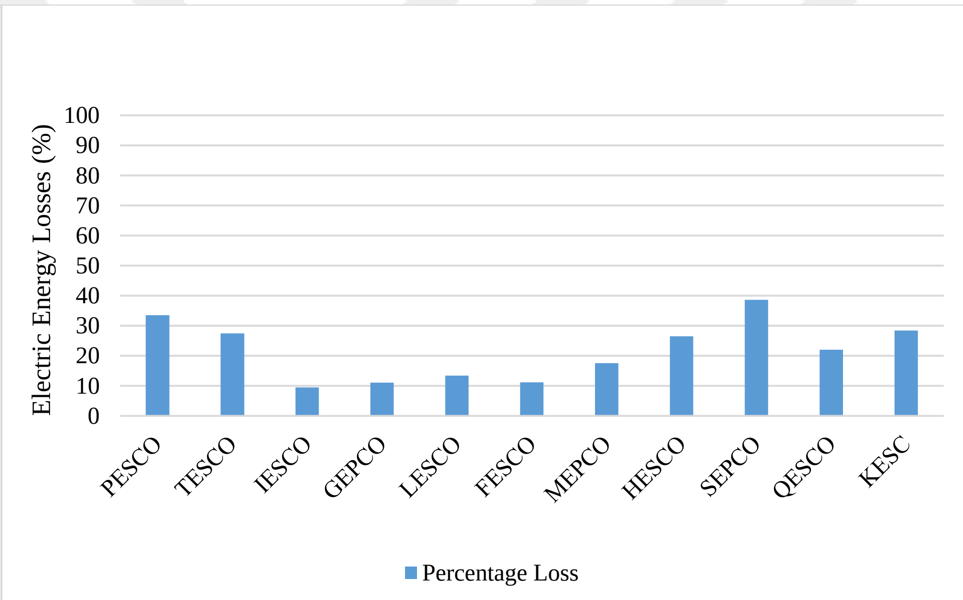

Figure 3.23 Distribution company-wise losses (in order of regional situation), 2014

PESCO, TESCO, SEPCO and HESCO can be seen as the worst performers in terms of energy losses. Energy lost by distribution in their systems is 30% and above. IESCO's, GEPCO's, LESCO's and FESCO's performance in minimizing the distribution losses is in par with the systems of the first world countries. These companies are home to industrial areas, and therefore the government gives more attention. Surprisingly, KESC being under the private sector, has not been able to reduce the losses.

Appendix G

Reasons for Problematic Situation of Electricity Sector

1. *Circular debt*

This can said to be one of the major reasons for the problems. To keep the energy cost low, the government subsidized the fuel prices but is unable to pay back the energy companies. As a result, these companies are in maximum debt to the fuel suppliers. This has resulted in a curtailed, and even a halted, fuel supply- further resulting in lesser power generation.

2. *Absence of adequate investments*

Although there are a large number of projects that are proposed, including hydro, thermal and renewables- but insufficient funding has hampered their initiation. The existing infrastructure is in great need of repairs, refurbishment and overhauling as seen in chapter 3. Many power plants are in need of new equipment, the transmission and distribution system needs upgrades and repairs, but all this is halted due to lack of funds.

3. *Reform and Governance issues*

The energy policy of Pakistan is only partially implemented due to poor management. Even though, a number of bodies and committees are established, but none of them seem to bring any positive change. Corruption and lack of knowledge has led to confusion in the sector. Apart from the privatization attempt in 1990's, there has been no major upgrade to the whole infrastructure. The complete privatization of the system has not been achieved as planned, and only thermal sector is under private control, that also partly. Rest of the system is suffering under the public sector, lacking integration and solidarity. The policies are unattractive to private investors due to presence risk and possible failure.

4. Payment issues

The electricity sector of the country faces a major issue of non-payments. Power theft is common amongst the general public. People attach hooks to main power lines and draw electricity without a metered connection. A large number of high officials are subjected to free electricity, and based on their lavish lifestyles, the sector has to face major payment deficits. A number of companies and industries are unable to make huge electric bill payments as most of them are facing revenue losses. In 2010, PEPCO reported an amount of $1 billion in unpaid bills (NEPRA 2011).

5. Security issues

Pakistan has been a warzone for more than a decade now. Terrorism and militant operations have affected all the sectors, including the energy sector. Unfortunately, the country's major energy resources are found in threatening areas. Most of the gas reserves are found in the province of Baluchistan, where there is a strong establishment of militant groups. The hydro and oil resources are found in the province of KPK, where the law and order situation is thin due to presence of Taliban group. These facts naturally deter any investor or agency trying to setup a harvesting site.

Many terrorist activities took place in the past, including bombing the pipeline or sabotaging power plant sites. Apart from this, there has been kidnapping and killing of foreign workers operating in the energy industry. The Army is only able to take action after an event has taken place. Law and order situation in Pakistan is alarming, repelling the interests of investors both international and local (Mills 2012).

6. Tension between Provincial Governments

There is a lack of coordination between the central and provincial ruling parties. For example, the KPK government complains about injustice in terms of asset and service allocations, resulting in their non-cooperation. The central government is therefore not able to easily initiate a project in the KPK region. Even the local population opposes the federal plans of setting up hydro plants, showing concerns of silting up of local water resources. The government is unable to provide with adequate compensation to these people (Mills 2012).

The government is also unable to convince the provincial government of Baluchistan and Sindh to harvest the coal and other mineral resources, due to lack of compensation to the general public. It is a general thinking of the minority population, that the central government is just exploiting their resources in order to further develop the 'already developed' areas of Pakistan, mainly the province of Punjab.

7. *Absence of local Industries and Engineering Expertise*

There are no large industries and factories, which can produce the components of an energy system, including extraction plants, refineries, power plants, transmission equipment etc. All of this equipment is imported, making it more expensive for investors. This lowers the interest of companies to make investments in large projects.

There is no research and development foundation, where engineers and scientists could work together to improve the energy system in a technical sense. There are no major laboratories or research centers. Although the education system is quite comprehensive, but there are no specific fields which teach students about the energy systems, in particular the Pakistani case. This leads to unawareness of the public about the problems and crisis, and their solutions (Mills 2012).