Integrated Urban Energy Planning in Twin Cities of Islamabad and Rawalpindi

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THESIS ACCEPTANCE CERTIFICATE

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Dedication

Thanks to Allah Almighty for His blessings and kindness. I dedicate my research to my family for their efforts and struggles throughout my academic career and my honorable Supervisor Dr. Kafait Ullah.

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Abstract

Decentralization of the power system has influenced the urban level electricity modeling and planning with the renewables being incorporated in the system. Energy demand and supply is of fundamental importance dealing with the sustainable development of any region. This research analyzes the bottom up energy approach in LEAP model to analyze the electricity demand and supply of all sectors of Islamabad and Rawalpindi. The importance of this research is that it will help explain the urban electricity issues and will help with the energy planning and modeling at urban level. There are mainly six sectors that account for demand of electricity in both Rawalpindi and Islamabad namely, industrial, commercial, residential, bulk, agriculture and public lights. Both demand and supply side scenarios are developed using the econometric as well as end user approach. The demand side scenario includes the reference scenario (Ref) as per the growth rates of al the sectors along with the reference high scenario (Ref HI) and reference low scenario (Ref Low) based on the efficiency of the devices that could causes a change in the growth rates over the years. The supply side scenarios are the reference scenario (Ref), national ratio scenario (NAT) and renewable scenario (REN). Environmental aspects are also discussed and compared in the form of emission analysis for all the scenarios so that the best possible scenario could be analyzed. The results are in favor of the renewable scenario which not only provide an effective demand requirement but also provides the environment friendly emission analysis. The overall results of these scenarios will help provide sustainable demand as well as supply side policy concerns in this region.

Keywords: LEAP, Urban Planning, Integrated Energy modelling, Energy Planning, Supply and Demand Side Analysis

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List of Publications

Muhammad Tayyab Waheed, Kafait Ullah, Usama Perwez **“Electricity Consumption modelling in the industrial and commercial sector of Islamabad and Rawalpindi”** 38th all Pakistan Science Conference held under the auspices of the Pakistan association for the Advancement of Science with the theme being Energy Crisis and their Solutions in Pakistan

List of Abbreviation

LEAP	Long Range Energy Alternative Planning
IESCO	Islamabad Electric Supply Company
ISB	Islamabad
RWP	Rawalpindi
Ref	Reference
NAT	National Ratios
GHG	Green House Gases
TWh	Tera Watt Hours
GWh	Giga Watt Hours
MWh	Mega Watt Hours
MW	Mega Watt
PPIB	Private Power and Infrastructure Board
PC	Planning Commission
PBS	Pakistan Bureau of Statistics
GDP	Gross Domestic Product

Chapter 1
Introduction

1.1 Energy in global context

With the exponential rise in the world's population, it has become almost impossible to create a balance between the energy demand and the population growth. The energy resources are diminishing due to population explosion. Urbanization has caused a major drift in the energy consumption and it has become hard to sustain the system. Currently around 50% of the people are living in the urban areas and the growth is expected to rise in the near future [1]. Energy economy is related to the energy consumption and this relation could also be explained in terms of income growth and growth in energy consumption. Developed countries are more effected by this relation and other countries may not suffer much from this as gross domestic product (GDP) is affected by energy consumption [2].

Energy is one of the fundamental factors in order to sustain the economy for all domestic, commercial and industrial activities. Energy shortages give birth to problems in almost all the sectors including the employment, economic growth and the social cohesion of the society [3]. One of the prime uses of energy is in the form of electricity which further determines the growth and development of a nation. There are great degree of efforts globally to develop a sustainable economic system that could contribute towards the efficient energy model [4, 5]. However, Pakistan is facing a horrendous disaster and crisis in the electricity sector from the last two decades. The population explosion and the uplifting industrialization and urbanization has increased the electricity demand beyond sustainability [6]. Multiple power and energy planning policies have been introduced to solve the energy conundrum in the region.

With the energy being the basic need for a sustainable human life along with the economic growth and development, the perpetual increase of population and industrialization is increasing the demand of energy [7]. The modern and clean resources of energy have reduced the usage or dependence on firewood, kerosene and diesel-based power generation. Hydro power is one of the most effective and efficient ways of energy as it not only provides the clean and secure energy, but it also assists with the water supply and storage. International energy agency (IEA) demonstrates the importance of hydropower in terms of power generation and also as to how this is the most rudimentary form of renewable electricity generation [8]. The global hydro production is observed to be around 3288 TWh and the overall potential of hydro is observed to be around 16400 TW/yr. Renewable energy resources along with hydropower potential has gained importance over the last decades of around 4% increase per year and globally the installed hydropower capacity has increased by 39% from the year 2005 to 2016. Hydropower is delivering almost 71% of the world's renewable electricity [9].

1.2 Status of Energy in Pakistan

Pakistan is facing a drastic energy situation over the last two decades. The main reason of this imbalance is the meagre economic conditions along with the poor policy as well as infrastructure and use of oil and gas for electricity production instead of paying attention to the renewable energy resources. Pakistan is blessed with high potential of hydro energy but still due to lack of infrastructure and up-dation of already existing system, there is a shortage of around 4 to 5 GW from the last 2 decades [10]. The energy demand of Pakistan has reached over 21,200 MW while the supply is only 16,548 MW [11]. Average energy per capita for Pakistan is 405 kWh, while average energy per capita in India and United States of America is 1122 kWh and 12071 kWh respectively, which explains the quality of life, due to the low per capita energy consumption, is pretty low [12]. The domestic sector only has gone over to the increased electricity consumption from 22.8 TWh in 2000 to 36.1 TWh in 2011 because of the urbanization and upgradation of standard of living [13]. Energy generation and its development and growth is important for socioeconomic growth. For sustainable energy supply, there is the need for renewable energy generation through solar and hydro power plants to eliminate all coal power plants as coal or other fossil fuels are not an environment friendly energy source or clean coal technology has not been efficiently applied in the system.

1.2.1 Energy planning situation in Pakistan:

Pakistan has always been an energy importer even though there is a huge potential for energy generation. The demand and supply side gap seem to be increasing over time and still no proper policy is devised to assess the energy situation. The electricity theft has caused some serious damage to the already fragile energy situation in the country.

One of the primary reasons of the energy conundrum in Pakistan is the lack of proper policy and planning at national, regional or urban level. There are varied and disintegrated policies at national level like petroleum policy, power policy, renewable energy policy, energy conservation and efficiency policy and climate change policy. Developed countries are focusing towards the sustainable future by analyzing the energy situation at regional or urban level. Urbanization has provoked the idea of sustainable future which demands proper energy policy and planning. Urban planning is important as it helps analyzing the issues and demand of all the sectors at Urban level.

1.3 Problem Statement

Energy is the basic need of life and the demand of energy has been exponentially increased over the last 2 decades because of the population explosion and with the digital devices being the part of life. There have been some serious issues regarding the energy planning and policy at national level. One of the fundamental reasons of all the energy related issues is the lack of energy planning at provincial, urban or regional level. Urbanization has revolutionized the modern world and the urban areas are expanding at enormous rate. Islamabad and Rawalpindi are the twin cities with ever increasing energy demand. There are almost 3 million of people living in the urban areas of these cities. There hasn’t been much contribution towards the urban planning in Pakistan and that is why Pakistan has suffered major electricity crisis since the last 2 decades. By providing proper urban energy policy and planning, we can overcome the supply and demand as it will help analyze the major issues of all the sectors like residential, commercial, industrial, bulk, agriculture and public lights at urban level. Electricity demand and supply analysis is of the prime importance to assess the situation in terms of consumption which will further help analyze the demand and supply side gap.

Now the primary focus of our research is to provide the energy consumption modelling of Islamabad and Rawalpindi which will help assess the urban energy policy requirements. The overview of the electricity structure of Islamabad and Rawalpindi will be analyzed. All the sectors of Islamabad and Rawalpindi are the part of this research, so it will help with the policy making at urban level. Also, different alternative energy scenarios will be analyzed including the future hydro potential and the effect of renewable energy penetration into the existing system. The electricity demand, supply history, current status and future prospects will be analyzed with the help of Long-range energy alternative planning (LEAP) tool for modeling of Islamabad and Rawalpindi.

1.4 Level of Research Already Carried Out on the Proposed Topic

A lot of research has been done on the energy modelling at urban level using LEAP. However, there has been a huge gap between the effective electricity consumption modelling as there is no proper evidence of consumption modelling for Islamabad and Rawalpindi. Electricity consumption modelling of industry, commercial, residential and agriculture have not been thoroughly analyzed. Various tools have been used for energy planning purpose including econometric models including LEAP, TIMES/MARKAL and EnegyPlan. Energy modelling and forecasting have been the major directions for sustainable future generation. Urban energy planning leading to the smart city concept has been the fundamental of this research. LEAP has been used for energy planning in a lot of countries including the Java Bali Indonesia, Sau Paulo Brazil, Switzerland, Korea, Japan, China, Mexico and Pakistan. However not much emphasis has been on the urban energy planning. Energy demand and emissions analysis was done with the help of LEAP model in Pakistan. Up till now LEAP has been successfully used in more than 150 countries worldwide for different purposes.

1.5 Reason/Justification for the Selection of the Topic

The motivation behind the idea is to evaluate energy consumption policy at urban level or urban planning in order to analyze major issues regarding energy management in Islamabad and Rawalpindi. After the modelling of all the regions of Islamabad and Rawalpindi including the residential, industrial, commercial, agriculture, public lights and bulk sectors, a proper policy could be devised in the region, different scenarios will also propose a way to reduce their energy consumption through energy efficient ways and conservation measures. This research will also give a future prospect about how energy consumption modelling could help build confidence towards the energy future leading towards the smart city electricity planning. Long range energy alternative planning (LEAP) is a tool which is used to identify the consumption modelling as well as the energy supply and demand management. LEAP modelling will help understand the future prospects of energy and devise an alternative way of energy for the region.

A lot of research has been carried out in almost all the developed countries which helps in analyzing the policy issues.

1.5.1 Relevance to National Needs

Currently Pakistan is facing Energy crisis, to understand the basic framework of energy needs and requirements at urban level will better help with the energy planning and policy making. Along with the electricity planning, the alternative scenarios will discuss the benefits of renewable energy penetration into the system and proper policy direction at urban level. This research will also help in building the confidence towards the renewable energy because of the no emissions and effective efficiency of renewables.

1.5.2 Advantages:

The major advantages of this study include

- Long-term forecast of energy of demand and supply side.
- Comprehensive analysis of electricity demand of all the sectors.
- Electricity supply side analysis with alternative scenarios to regulate the electricity supply.
- Will help the government in policy making and devising proper policy and planning at urban level.

1.5.3 Areas of Application

- It may help governments' policy making institutes to devise upcoming policy document.
- Sectorial based analysis will help understand the nature of the problem.
- Industrial consumers may be influenced by the renewable energy incorporation in the system and may adopt this to keep the business running.
- This research could be the role model for other cities as this research includes all the sectors, so it will be easy to compare results of other cities with this research.

1.6 Objectives

- Analysis of all the sectors leading towards the proper policy and planning.
- Evaluation of Energy modelling of Islamabad and Rawalpindi using leap model.
- Alternative energy resources like renewable energy analysis and incorporation to the existing system.

- Future projection of both demand and supply side of the area.
- To propose an efficient consumption behavior to reduce the energy requirement and load from the grid.
- Development of different scenarios and comparison of the result will provide the best possible scenario in the long run. As three alternative scenarios are discussed at the supply side.
- Urban planning and policy recommendations.

Summary

Pakistan has suffered a lot from the energy conundrum recently. The fundamental causes of this issue are the poor or inadequate policies, exploitation of resources and regional or political conflicts. The demand and supply gap seem to be increasing with time and the major reason has been urbanization and population growth. The hydro power potential which is a major strength has not been fully utilized, that’s why the energy situation is getting worse in the country. Islamabad and Rawalpindi have around 3 million of population with ever increasing energy demand. All the sectors including residential, industrial, commercial, agriculture, bulk and public lights have been analyzed in this research. The primary focus of this research is to analyze the urban level of electricity consumption of all the sectors. LEAP software has been used for the analysis with the 2016 as the base year and 2050 as the final year. Multiple scenarios have been discussed to provide a sustainable solution at the urban level. The results will contribute towards the policy making to overcome the demand and supply side gap.

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Chapter 2

Literature Review

2.1 Global implementation of LEAP model

LEAP (Long-range Energy Alternatives Planning) is an integrated modeling tool that can be used to forecast the electricity demand as well as the production of a country or any region. It also helps in figuring out the energy utilization, generation and resources in all sectors of the economy. Both energy and non-energy sectors are well accounted for in LEAP. It is of supreme importance that we forecast the electricity demand to provide a sustainable solution to the future of electricity. Also, the infrastructure for developing countries is important as it influences the economic development. By generating different energy scenarios, the electricity problem of a state is analyzed and compared on the basis of cost and GHG emissions that are used to forecast energy demand and supply. Renewable energy helps sort out the issue of GHG emissions and provides better demand side management. In Maharashtra India LEAP model has been used for the electricity demand and supply analysis and the scenario generated includes business as usual (BAU), Energy conservation (EC) and Renewable energy scenarios along with the gross domestic products (GDP) and different values of electricity demand probable projections have been analyzed [1]. The econometric approach and system dynamics method are employed for the modern forecasting system of the influence of new factors such as internet age, marketization reforms, technological progress and consciousness of energy conservation and emission reduction. The quantitative electricity demand factors are also analyzed. A proper and individual classification of all the industrial and commercial sector has been considered along with the two methods which helps with the accuracy of the model. The quantitative effecting factors of electricity demand are analyzed. As the error of this model is only 1.7% comparing with error of trend extrapolation (2.81%), average growth rate method (8.27%) and grey model (10.30%) [2].

The lack of natural resources in countries leads to the dependence on the energy imports, for a sustainable system development the long-term forecasting of energy demand and supply is of supreme importance. Multiple research approaches have been carried out in order to express the past progression and current standing of energy policies in different countries. All these research approaches provide the related explanation as well as application of LEAP models in energy sectors along with helps with the upcoming GHG emissions as well as demand and supply concerns. Many countries make policies based on sustainable development goals including energy sectors to establish a liberal, orderly, efficient, clean, and sustainable energy demand and supply system. Steadying energy supply, growing energy efficiency, deregulating energy markets, highlighting energy security and environmental protection, improving energy research and expansion, and promoting energy education are the main included factors of energy policies [3].

LEAP is one of the most widely used software for energy forecasting and modelling around the globe. In case of Indonesia considering the population and electricity consumption, the electricity demand has been calculated for all the sectors following some key factors for base year 2010 to end year 2025 in the Sumatra island which is in western Indonesia. The key factors include the population, household size and electrification and electric intensity. Energy consumption seem to be uplifting with the development in any sector and the electricity demand forecasting helped analyze the fact that demand seems to be increased seven times from base year to final year [4]. Also the modelling of the Java Bali region of Indonesia have been analyzed and the mitigation analysis explains how the Paris agreement target could be easily met by switching from coal to natural gas [5].

There has been a great degree of research and analysis on the African power supply and demand scenarios. There has been a great degree of deficiency of electricity in the Africa as almost two third of the population is still living without the electricity. Sustainable modelling of the long-term supply and demand has been forecasted using the LEAP model. The scenarios developed are Business as Usual scenario (BAU), Renewable Promotion and demand and supply side efficiency scenarios. The results show a great uncertainty as even in the BAU scenario it would be almost impossible to sustain the system as 60% of the energy demand would be hard to meet even by 2050. The renewable scenarios are offering 44% of electricity by 2050 with a little or no emissions. Demand side efficiency scenario will manage the energy balance to a suitable condition with the supply side efficiency leading to the 60 TWh and GHG emission reduction to 147 million metric tons. The favorable scenario is the renewable scenario with compromising development and sustainability of the system [6].

Shandong province of China has also been studied in terms of energy consumption modeling. There has been an exponential economic development in this region during the last decade. A major energy shortfall has been observed due to the increased demand of energy in the region and the LEAP software has been implemented for the energy forecasting for 2010, 2015 and 2020 by creating a program scenario with high- and low-level peaks. A 5% of annual increase has been observed which will affect the sustainability of the system [7].

LEAP has been used in many countries for energy sector modelling and analysis and for CO2 mitigation or environmental inspection. The LEAP model has already been used to explore various scenarios in the energy sectors in Pakistan [8], China [2, 7], Iran [9, 10], Africa [6], India [1], Korea [11], Japan [12]and Taiwan [3]. The optimization method in LEAP helps with the investment as well as power system development. LEAP has also been actively applied to energy and CO2 impacts of power expansion with special focus on local energy sources like a case of landfill gas in Korea [13], nuclear in Korea and Japan [11, 12]and renewable in Southeast Asia [14].

2.2 Implementation of LEAP model in Pakistan

Electricity is one of the fundamental energy source and Pakistan is blessed with huge potential to generate electricity by hydro, coal and renewable resources. Understanding the consumption modelling by individual sectors of any region could help contribute a lot towards the policy making and modelling of the system. Pakistan is a developing country with ever increasing energy demand. Pakistan is suffering from the energy crisis since the last 2 decades due to the poor infrastructure and outdated model and structure. LEAP model has been implemented in the Sindh province to forecast or analyze the electricity demand. Three supply scenarios have been developed which are Business as Usual (BAU), renewable rich (RR) and Thar coal (TC). The projected electricity demand seems to have been extended to 116.93% over the base year 2014 [15].

China-Pakistan Economic Corridor CPEC has been the hot topic in Pakistan with the impact over the whole Asian continent. Sustainable development has been the fundamental approach that is under consideration and the modelling and analysis of

CPEC project has been scrutinized using LEAP model. Three scenarios have been analyzed in this research such as Reference Scenario (RE), Coal Scenario (COA) and Renewable Scenario (REN). In the analysis from 2013 to 2030 it's been observed that the expected energy demand on 2030 is around 110.5 billion KWh. To limit the forecasted demand of energy different supply side mix is planned and concluded that energy production using coal would be beneficial for Pakistan [16].

The population explosion and exponential increase in the electricity demand has caused an uncertain situation in the Pakistan. The productivity has been decreased due to the power crisis and the social order and structure has been hugely affected. The long-term electricity demand forecasting of the residential sector reveals that there has been a 3 GW of shortfall with per capita electricity consumption seems to be around 536 KWh [17].

The demand supply gap of Pakistan in 2016 was around 5000 MW. LEAP model is designed for the analysis of renewable energy policies and secure energy supplies. Different scenarios developed in this study for the cost-benefit analysis and emission of harmful gases because of electricity production. The most suitable, clean and cheap energy scenario for Pakistan is greater share of renewable resources which has minimum external cost with environment friendly supply of energy. While for the future energy needs, the optimization scenario based on current account is most expensive and harmful for environment as well [18].

LEAP has also been utilized in Pakistan for urban as well as regional or provincial level energy modelling. For overall Pakistan LEAP has been employed for energy security and renewable energy policy analysis [18], a long term forecast of electricity demand and supply [8, 19], future energy alternatives and institutions infrastructure analysis [20], electricity demand forecast and analysis of Sindh province [15], urban transport air pollution analysis [21], evaluation of biomass potential for renewable energy in Pakistan has also been studied [22] and multiple other mitigation and modelling analysis has also been analyzed.

2.3 Overview of energy forecasting tools

Energy policy simulation models have contributed a lot towards the energy modelling and multiple methods have been designed to customize the energy policy requirements. An energy model naming MIDESRAP (modeling the dynamics of energy, supply, resources and pollution) was developed in 1999 and has been used in Pakistan for energy policies analysis in 2001. Generally, modeling and simulation have served the energy policy domain, but system dynamic models in particular have contributed more towards the energy policy evolution. For the validation of the models the Thiel's inequality statistic method has been used. The validity and authentication and acceptance of any model by the researchers is necessary for global use [23].

The primary focus of the energy planning and modeling has been on the effective and authentic electricity demand and supply analysis. The papulation explosion has caused the exponential increase in the electricity demand from the last 2 decades. The current structure does not seem to have been fulfilling the electricity demand because of the lack of effective modeling tools for electricity forecasting and planning. This research analyzes the different methodologies that has been used in the recent past for energy planning and projection. Artificial intelligence along with the parametric methods have been utilized for energy demand forecasting. However multiple other models have been developed for electricity demand forecasting such as LEAP energy model, Regression models, ARIMA models, Time Series Models, Grey prediction models, Co-integration models and Input-Output models. There have been four major factors highlighted in this study that could help with the better understanding and modelling such as Accurate and reliable data, Technology, Capacity and building and Planning and Implementation [24].

In this study the long run and short run dynamic relation has been estimated between electricity consumption, real income, real price and domestic price over the period of 1978 to 2012.There are 6 major sub-sectors that are responsible for the electricity demand in Pakistan such as industrial, commercial, residential, agriculture, government and public utilities. The technique employed for the analysis are, the pooled mean group (PMG) and the dynamic panel co-integration. The four major implications have been observed such as the it could help policy makers with the future demand and generation model, help with the upgradation of the existing infrastructure, spending on the new mini hydro plants and construction of new water reservoirs. Renewables incorporation and investigation in the form of solar, wind and biomass will be enough to support the system [25].

There are multiple regression models that could help with the estimation of the current and future planning. Holt-Winter and Autoregressive Integrated Moving Average (ARIMA) has been analyzed in this research. There has been a secondary time series data from 1980 to 2011 as the time series data help with the long-term projection. Energy forecasting has been the major tool for the development and economic growth and the total and sector wise electricity consumption has been analyzed in this research. As the supply seems to have been less than the demand in the projected time so this study also provided alternative options to overcome the supply-demand gap and reliable energy supply options. The suggestions are directing towards the policy makers ensuring the productivity along with the efficiency of industrial sector. The result obtained from the Hold-Winter model are far more efficient that ARIMA model [25].

Apart from all the capacity and potential of the energy resources Pakistan is still facing numerous problems and challenges to overcome the demand supply gap which has plummeted to around 5MW. All policies and plans have been examined since the initiative of power and energy planning in 1960s. The failure is because of the inappropriate or inadequate use of energy modelling tools like TIMES/MARKAL, LEAP, MESSAGE etc. The study recommends different integrated energy modelling and planning tools to develop sustainable energy policies in Pakistan. The issues addressed regarding the energy department are lack of infrastructure, resources and professional competency. A comprehensive integrated energy policy (IEP) is required for Pakistan to overcome the energy crisis with the help of use of the updated models like LEAP, MARKAL and TED [26].

An updated energy planning tool named as TEEP (Tool for Electricity Energy Planning), with the same accounting framework that has been used in the LEAP, has been studied in this research for the area of Java, Indonesia. The bottom up modeling approach has been used in TEEP. The primary focus of this research has been on the generation cost (as per the fossil fuels and renewables) and the resource allocation implication. Two scenarios have been developed such as the coal fired power plants and the combination of Photovoltaic and the Geothermal power plants in combination with Coal power plants. The second scenario has the better results and efficiency than the first scenario which deals with only the coal fired power plants [27].

The central province in china named as Hunan is a major energy consuming province having a lot of industries and a rapid development rate. A lot of energy has been imported as the energy development and technology is very outdated with not much focus on the generation. This research is scrutinized to improve the energy utilization and reduce the consumption. LEAP and Logarithmic Mean Divisia Index (LMDI) are used in this research for the analysis. 2006 to 2015 LDMI was used for the study and the base year has been set to 2016 for the LEAP with the end year being 2050. GDP growth has been the major factor causing the imbalance in the demand and supply side management [28].

There is also a study on the Iraq electricity demand forecasting as being a war zone for the last 2 decades the economy and power infrastructure has been strongly affected. This research explains the long-term electricity demand forecasting of Iraq using the ANN model and the linear logarithmic regression model under the time period from 1994 to 2013. Accurate and realistic load forecasting is important in terms of energy infrastructure management and economy. The two primary reasons are acknowledged as the cause of the energy gap: high growth rate and security conundrum. The linear logarithmic model has observed to be more efficient than the ANN model because of its flexibility and reliability [29].

2.4 Electricity Infrastructure study in Pakistan

The electricity infrastructure has been considered in order to provide a comprehensive insight into the system. A thorough infrastructure analysis has been observed in the research by Dr. Kafait Ullah. The major infrastructure analysis explains as to how there is a great degree of imbalance between the demand and production capacity of Pakistan. The primary focus of this article is to discuss the infrastructure and production to consumption chain. There has been a great degree of dispute about the liberalization of the institutional changes and also the lack of direction and component of institutional changes needs to be investigated. As the institutional changes in the electricity sector have shamefully failed to produce desired results and investment shortages, governance issues, policy failures, incomplete implementation of reforms and some other factors seems to be the reason of infrastructure failure [30].

Pakistan's electricity crisis along with the alternate energy sources and policy implications and future energy development recommendations have been analyzed in this research. The major issues seem to be the insufficient installed capacity, along with the weak and fragile infrastructure, on policy and planning level there are shortages or revenue and circular debts. The implementation of the alternate energy resources has also been analyzed considering the National energy security plan (NESP). There are multiple suggestions or recommendations discussed in this research to overcome the crisis and to promote the alternative energy in the current power structure. The fundamental suggestions are improved governance, support to hydro and nuclear plants, grid connected energy development of solar, wind, biomass and micro-hydro projects. Along with all these factors there should also be a law and order, research centers should be developed for the development of renewable energy and conflicts and disputes regarding the development of hydro projects should be resolved [31].

A short-run study to provide the solution to the power crisis in Pakistan has also been analyzed. Pakistan energy crisis affected the economy, industrial activities and employment along with the standard of living. Since 2000 there are three major episodes of growth, of the economic performance of Pakistan, being the low, high and low. The effective and efficient utilization of current resources could help eradicate the short-run shortage as it could help increase the 5% of power generation and almost 12% of the revenues. There is a dire need to build trust regarding the renewable energy sources as the solar, wind and hydro have more than enough potential to overcome all the barriers [32].

A comprehensive study has been conducted by the World Bank development research group regarding the chaos in Pakistan's power structure. The gap in the supply and demand has been very critical from the last 3 decades. The politicization of the power structure has fanned the flames with the fingers point towards the government officials being responsible for the crisis and also threatening the legitimacy and credibility of the government along with the institutional crisis and governance failures. Th is research focuses on the key issues and problems of the Pakistan's electricity sector and also analyzing the policy recommendations to overcome the power crisis. Multiple issues have been pointed out regarding the Pakistan's power structure like the electricity governance reforms, ineffective power generation mix, lack of an effective and credible regulatory regime has undermined incentives for private investment, tariff structure has been below cost and market structure has been dominated by the monolithic entity. The decentralization of the power system is also required for the betterment of power structure like privatization of the distribution along with the effective energy efficiency policy and regional market integration are the important steps [33].

2.5 Research Gap

Energy modeling and policy has been one of the most dynamic approaches to assess the energy situation as per the futuristic perspective. There is a dire need to address these issues by devising proper policy for the sustainable future. There is a huge difference regarding the policy and planning in developed and developing countries. The availability of data is one of the major challenges in developing countries which is the root cause of the lack of policy and planning. In Pakistan there hasn't been any research at the urban level or even provincial or regional level. Some researches are trying to address the mitigation or emission analysis at regional level but no even a single research is addressing the demand and supply issues at regional or urban level. Some researchers have recently been working on the energy forecasting using different tools like LEAP, MARKAL, TIMES and ARIMA etc. There is still no area specific proper research at regional or urban level addressing the energy demand and supply side issues. Also, not even a single policy is available at provincial or urban level. The main idea of my research is to address the twin cities of Islamabad and Rawalpindi and provide a complete analysis and this research will provoke the policy and planning and will promote this idea for other big cities of Pakistan. I am addressing all the sectors of twin cities including the residential, commercial, industrial, agriculture, bulk and public lights. Along with the demand and supply side issues I am also addressing the complete environmental issues along with the renewable incorporation into the current system.

Summary

The global and Pakistani perspective of the already conducted research has been discussed in this section. Globally, there has been a lot of research at national, regional and urban level of energy modeling and planning using LEAP model. However, in Pakistan LEAP has not been used much at the urban or regional level. There is the evidence of some mitigation analysis of LEAP but overall no modeling has been done at urban level. Literature review of different modeling tools like TIMES, MARKAL, ARIMA, LEAP and TEEP have also been conducted for energy supply and demand forecast. LEAP is observed to be one of the most reliable software with custom data and modeling requirements. It has been mostly used globally due to the custom scenario building with the penetration of new energy sources in the system like renewables. Urban level planning is of supreme importance and a lot of literature has been discussed for both developed and developing countries like China, Brazil, Africa, Indonesia, Japan, Korea, India and Switzerland. No energy planning at urban level has been analyzed using LEAP or any other tool so there is a major gap of the research in Pakistan's regional or urban perspective. LEAP has been used in Pakistan at national level of energy forecasting but in my research, I am using LEAP for modeling, planning and forecasting of energy at urban level for Islamabad and Rawalpindi.

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Chapter 3
Overview of Islamabad and Rawalpindi Electricity Sector

3.1 Power Structure of Islamabad and Rawalpindi

Islamabad and Rawalpindi are known as the twin cities. The urban areas of Islamabad and Rawalpindi has the population of around 3 million [1]. There hasn't been much contribution towards the smart city idea in Pakistan due to the centralized power structure. This research will explain the benefits of the urban planning and renewable incorporation in the existing system leading to the smart city concept. The overall structure of Pakistan's power sector could be seen in the Figure 1 below.

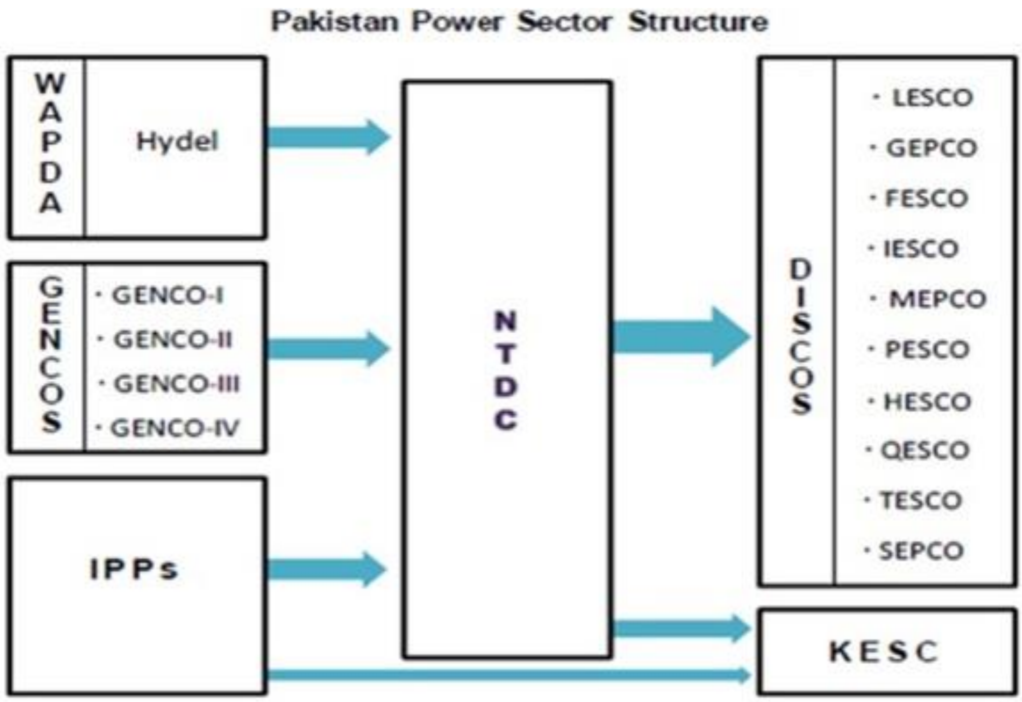

Figure 1 Power sector structure of Pakistan

Islamabad and Rawalpindi do fall under the Islamabad Electric Supply Company (IESCO). IESCO was formed in 1998 to take over the responsibilities of WAPDA's division named as Islamabad Area Electricity Board (AEB). The primary purpose of the IESCO is to sell power in the areas from Attock to Jhelum including the river Indus to river Neelum in Kashmir [2].

Islamabad and Rawalpindi do fall under the jurisdiction of IESCO and it has been supplying power to Islamabad and civil administrative divisions of Rawalpindi with the total number of consumers being around 2.67 million [1]. There are 6 major sectors in the Islamabad and Rawalpindi that require the electricity for operation such as residential, commercial, industrial, agriculture, public lights and bulk, the bulk includes the government institutions and major share is been provided to the government power authority of AJK. The table below expresses the total consumers from all the major sectors [3].

Table 1: Number of Consumers under IESCO

Sector	**No of consumers (million)**
Domestic	2.27
Commercial	0.37
Industrial	0.02
Agriculture	0.008

3.1.1 Sub-stations in Islamabad and Rawalpindi

The table below shows the number of sub-stations for Islamabad and Rawalpindi [3].

Table 2: Sub-stations under IESCO

Sub-Station power rating	**Number of stations**
132 KV	77
66KV	4
33KV	2

3.1.2 IESCO Feeders

IESCO has been fed by 5 major feeders such as New Rawat, Hazro, Bhone, Museum and Sitara Market [3]. However, the overall Islamabad and Rawalpindi have been fed by the New Rawat feeder.

The Table 3 below explains the IESCO feeders and their characteristics [3].

Table 3: IESCO feeders and their characteristics

Feeder name	Length (km)	Peak Demand (KW)	Line Loss (KW)
Hazro	57.95	4005	927.9
New Rawat	27.45	2579	254.6
Bhone	142.55	3374	472.2
Museum	30.1	5906	320.9
Sitara Market	8.5	3048	59.0

New Rawat feeder distributes power to the Islamabad and Rawalpindi region and the other feeders and the other feeders distribute power to the other regions of IESCO. Also the Rawat grid station which was of 220 KV level was updated to 500 KV in 1997 by NTDC [4].

The total power delivered to the New Rawat feeder is around 2480 MW which is then distributed to the Islamabad and Rawalpindi regions.

The Figure 4 below shows the distribution network map of IESCO [3].

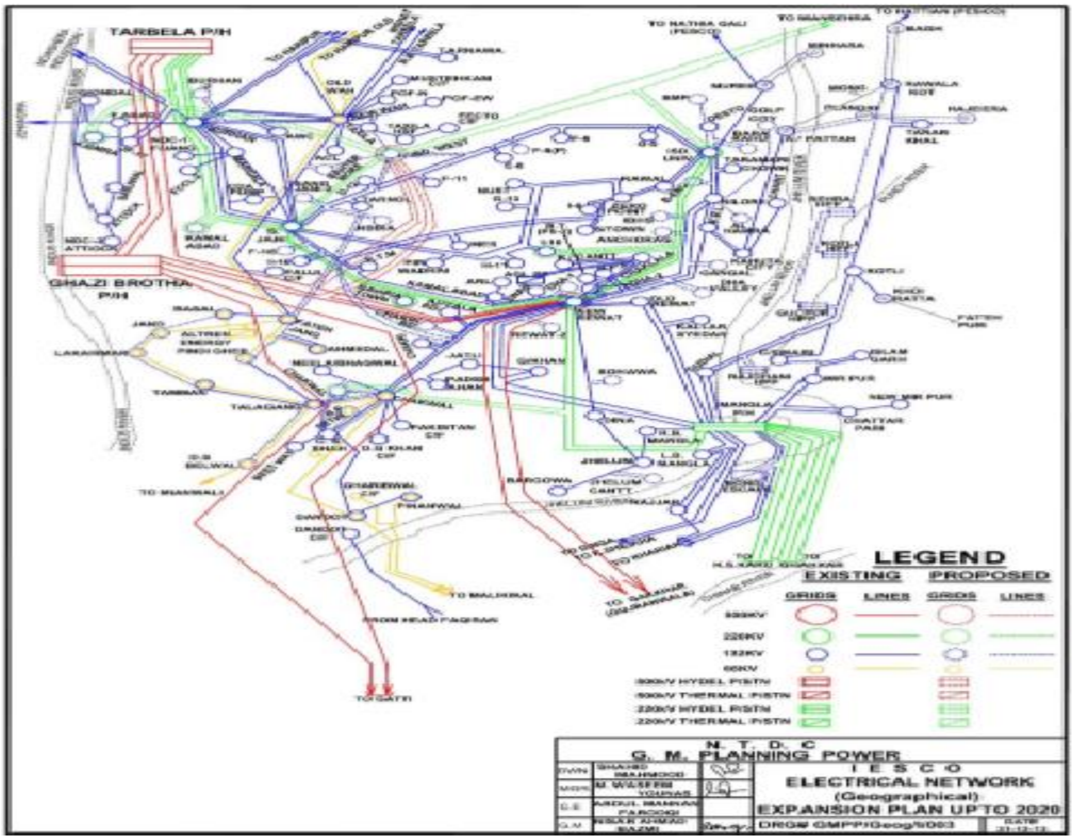

Figure 2: Distribution Network Map (IESCO)

3.2 Total Demand of Islamabad and Rawalpindi

Islamabad and Rawalpindi have been properly analyzed and according to the IESCO, both Islamabad and Rawalpindi are divided into divisions. Islamabad is divided into 3 divisions namely division 1, division 2 and division 3 and similarly Rawalpindi is divided into 7 sectors. The division 1 includes blue area, F6, G6, g7, Khana Dak, Nilore and Tarlai regions and division 2 includes F11, F8, G11, G9, I10 and I9 regions and similarly, division 3 includes the Bara Kahu 1 and Bara Kahu 2 regions. The Rawalpindi is divided into the 7 sectors like Satellite town, Pindi City, Pindi Cantt, Westridge, Tariqabad and Rawat. The total demand of these regions in 2016 was observed to be around 1976 MW [2]. Islamabad and Rawalpindi are addressed as the separate units as per the IESCO data set. According to the report published by NEPRA (in 2015-16) IESCO has been ranked number one on the basis of the performance among all distribution companies and this performance was based primarily on the safety of the system and transmission and distribution losses [5].

3.3 Total Supply of Islamabad and Rawalpindi

Total supply of Islamabad and Rawalpindi has been observed to be around 2480 MW and the demand is balanced by the supply after all the losses. The New Rawat grid station has been supplying electricity to Islamabad and Rawalpindi and the contribution of all the sources to the electricity supply could be seen in the Table 4 below.

The New Rawat grid station receives the power from the different sources as shown in the table below

Table 4: IESCO electricity sources

Source	**Units**	**Power (MW)**	**Fuel**
Tarbela	1	1410	Hydel
Ghazi Brotha	2	590	Hydel
Mangla	2	200	Hydel
Altern Energy	1	31	Gas
AGL	1	165	Diesel
Total		2200	

The overall contribution is as the hydel being around 2200 MW, Oil 165MW and gas 31 MW [3].

Summary

Islamabad and Rawalpindi do fall under the Islamabad Electric Supply Company (IESCO) and all the sub-stations and supply side of the IESCO has been analyzed in this section. There are around 2.6 million consumers that fall under the IESCO. All the sectors have been individually analyzed. The major focus has been on the electricity demand and supply of the region. The overall structure of Pakistan electricity sector and then the structure of IESCO has both been analyzed and the demand of Islamabad and Rawalpindi region has observed to be around 2000 MW. The Islamabad and Rawalpindi are further divided into divisions like division 1 (blue area, F6, G6, g7, Khana Dak, Nilore and Tarlai), division 2 (F11, F8, G11, G9, I10 and I9) and Bara kahu division do fall under the Islamabad regime and Rawalpindi (Satellite town, Pindi City, Pindi Cantt, Westridge, Tariqabad and Rawat). All these divisions are separately examined and energy demand and supply is modelled.

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Chapter 4

Methodology

4.1 Review of Modelling Tools:

There are multiple different tools that are used for planning and energy modeling around the globe depending upon the requirements of the data available, time frame, optimization, geography and environment of the area and energy policy considerations. The most common and effective energy modelling and planning tools are MARKAL/TIMES, MESSAGE and LEAP [1].

Table 5: Type of each tool reviewed

Tool type	Scenarios	Simulation	Top-Down	Bottom-Up
TIMES/MARKAL	Yes	No	Partially	Yes
LEAP	Yes	Yes	Yes	Yes
Invert	Yes	Yes	No	Yes
MESSAGE	Yes	No	No	Yes
MiniCAM	Yes	Yes	Yes	Yes

Table 6: Type of Analysis conducted by each tool reviewed

Tool type	Scenarios Time Frame	Time Step	Geographical Area
TIMES/MARKAL	50 years maximum	Hourly, daily, monthly using user-defined time slices	National/State/Regional
LEAP	No Limit	Yearly	National/State/Regional
Invert	50 years maximum	Yearly	National/State/Regional
MESSAGE	50+ years	5 years	Global
MiniCAM	50+ years	15 years	Global and Regional

Table 7: Energy Sectors Penetrations Simulated by Each Tool

Tool type	**Energy Sector Considerations**			**Renewable Energy Penetration Simulation**	
	Electricity Sector	Heat Sector	Transport Sector	100% Electricity Simulation	100% Renewable Energy Simulation
TIMES/MARKAL	Yes	Yes	Yes	No	No
LEAP	Yes	Yes	Yes	Yes	Yes
Invert	Yes	Yes	Partially	Yes	Yes
MESSAGE	Yes	Yes	Yes	No	No
MiniCAM	Yes	Partially	Yes	Yes	No

Table 5, 6 and 7 explains the review of different energy modeling tools. LEAP seems to be the obvious choice for the analysis here because of the data limitations and customization. Also, the analysis time frame could be as per custom requirements.

4.1.1 Potential of LEAP Model

LEAP (long range energy alternative and planning) is a significant tool that is used for the demand and supply side management of any system along with the production and utilization of resources. It was developed by the Stockholm Environment Institute (SEI) in 1980 in USA [2]. It is being provided for free for developing countries and academic purposes however corporate sectors and organizational institutes are to buy licenses.

The LEAP (long range energy alternative planning) is the elected model for the analysis and it is developed by the Boston University and Stockholm Environment Institute. This tool helps with the comparative analysis of energy and environment. The analysis and approaches are Environmental Impact Analysis, Equivalent and Cost Benefit Analysis and Scenarios Analysis and Energy demand analysis approach [2]. It also assists with forecasting the energy demand to futuristic perspective by interpolating the scenario over the number of years. In the light of imminent energy demand and supply, LEAP is an efficient tool for the policy making. Keeping the environmental aspects in view the software aids in ensuring environmental hazards and GHG mitigation effects.

Use of LEAP has been stretched to over 170 countries with more than 5000 users. Online training sessions are available in different languages including Chinese, Portuguese, Spanish, French and English. The LEAP is primarily used to assess the national energy system as it takes time horizon as a function over a period. There are multiple methodological models on the demand side used in LEAP, such as the bottom up approach, end use accounting and top down approach. However, on the supply side it offers capacity expansion planning and multiple accounting and simulation methodologies for electricity generation. There is a limit of optimization modelling in the LEAP as it doesn't support that. Further developments are being looked at along with the collaboration of International Atomic Energy Agency [3]. In conclusion, it could be observed that all energy related technological systems are being supported by this software. There is also the individual policy manager to deal with the individual policy measures and also a wide range of options for decommissioning and unmet demand costs. The output is observed in the form of sprouting system along with the time. The results in the form of charts, maps and tables could be imported to the power point or excel. The result obtained are in the form of demand cost, GHG emissions, air pollutants and multiple other custom results. The results offer multiple comparisons with the usual scenario and active policy scenario.

4.2 LEAP Model Development for Islamabad and Rawalpindi

The primary requirement of this model is the authenticity of data for energy modelling and planning. The authentic data is sometimes acquired by taking the average of 2-3 years of data of the base and previous years. In developed countries, the organized form of data is available on government websites or reports. However, in developing countries the data is usually sorted out from the multiple sources like data banks, reports and publications of various institutions. The availability of data is pretty crucial in Pakistan and the data needs to be organized properly to be used in the model as per custom requirements. My primary area of research is electricity modelling of Islamabad and Rawalpindi. The data has been collected from the multiple institutes or organizations, such as Islamabad Electric Power Company (IESCO) and Pakistan Bureau of Statistics (PBS), Energy year book and Planning Commission (PC), and some data has been salvaged from Private power and Infrastructure Board (PPIB) in the form of surveys and reports [4-8].

LEAP model for Islamabad and Rawalpindi based on the electricity consumption modelling with the demand and supply gaps or trends over the period from 2016 to 2050. Base year has been set to 2016 and end year is 2050. The Islamabad and Rawalpindi are taken into account as two separate units. Islamabad is further divided into 3 divisions namely division 1, division 2 and division 3 and similarly Rawalpindi is divided into 7 sectors. The division 1 includes (blue area, F6, G6, g7, Khana Dak, Nilore and Tarlai regions) and division 2 includes (F11, F8, G11, G9, I10 and I9 regions). Similarly, division 3 includes (Bara Kahu 1 and Bara Kahu 2) regions. The Rawalpindi is divided into the 7 sectors like (Sattelite town, Pindi City, Pindi Cantt, Westridge, Tariqabad and Rawat). We can observe both the combined effect of electricity demand of both the regions and the separate demand of all the regions and sectors. The supply of both Islamabad and Rawalpindi in BAU model is covered by hydro, gas and diesel electricity sources and in national ratios scenario hydro, gas, diesel, renewables are distributed as per the percentage of national ratio and in renewables scenario the gas and diesel load is put on the solar, nuclear and wind along with the hydro.

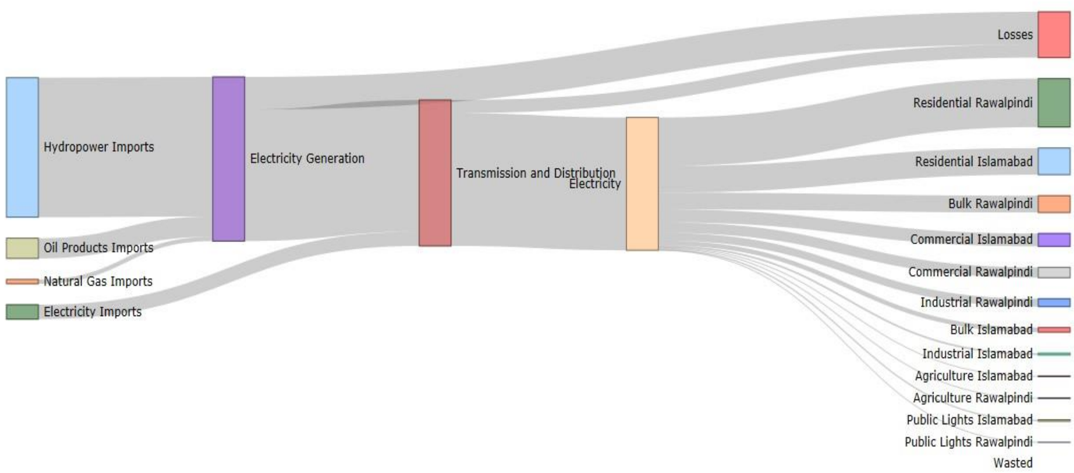

Figure 3 LEAP Model for Reference Scenario (Ref)

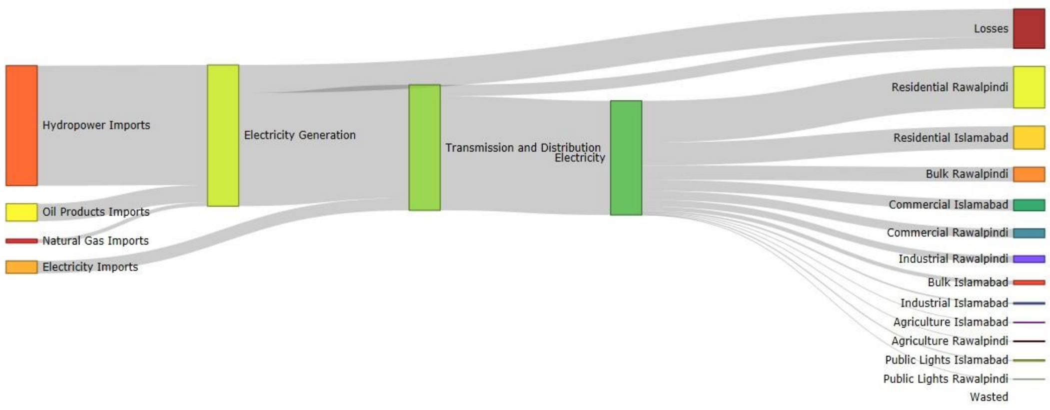

Figure 4: LEAP Model for National Ratio Scenario (NAT)

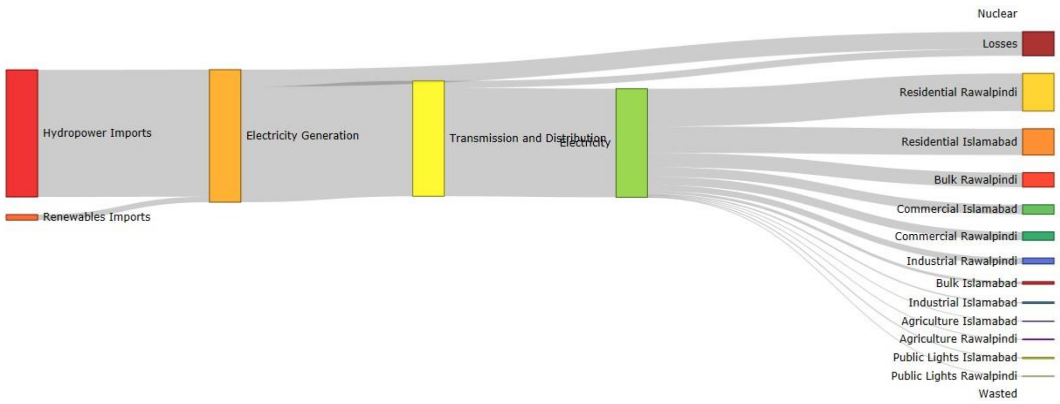

Figure 5: LEAP Model for Renewables Scenario (REN)

All three scenarios on the supply side could be observed in the images above as all these images represents the Business as usual scenario, National Ratios Scenario and Renewables scenario. LEAP model comprises of different modules in the form of key assumptions, demand, transformation and resources. The key assumption used for Islamabad and Rawalpindi model are GDP growth, population growth rate and income growth rate. The demand model has been divided into separate Islamabad and Rawalpindi divisions with further division into sub sectors like residential, commercial, industrial, agriculture, public lights and bulk. The transformation module deals with the supply side and consists of the distribution and electricity generation sub modules.

In transformation module, each module has got the option of feedstock fuel which in our case is hydro, gas and diesel as the electricity generation for this region is been fulfilled by these resources. Dispatch rule, historical production, process efficiency, endogenous capacity, exogenous capacity, maximum availability, life time of the plant, capital cost, fixed O&M (operation and maintenance) cost, variable operation and maintenance cost and fuel cost are required for each technology.

The demand of this region depends upon the electricity consumption of the sectors. The industrial and commercial electricity demand has been calculated by the use of econometric approach. The demand and supply scenarios are built where the demand side scenarios constitute the Business as usual scenario (BAU) along with the High scenario (HIG) and Low scenario (Low) to estimate the high- and low-level peaks of the demand side over the time period. On the supply side, we have the Business as usual scenario (BAU), National ratio scenario (NAT) and Renewable scenario (REN).

4.3 Data Collection and Sources

Data is one of the most important factors in order to observe the effective and efficient modelling and planning, a valid data has been gathered from the various resources such as visiting IESCO, Pakistan Statistical Bureau and Planning Commission along with different reports and publications. The data is then organized as per the model requirements as the data is not been provided in a ready to use form. Pakistan is a developing country and there is a huge problem with the data collection as I had to visit the IESCO, Statistical Bureau and Planning commission for the data collection. Some other data has been salvaged from the Private power and Infrastructure Board (PPIB) in the form of surveys and reports.

Table 8: Data Collection Sources

S.no	Data type	Source
1	Sector-wise demand and supply data	Islamabad Electric Power Company (IESCO)
2	Plans and Policies	Planning Commission (PC), Private Power and Infrastructure Board (PPIB)
3	Demographics and reports	Energy Year Book and Pakistan Bureau and Statistics (PBS)

4.4 Assumptions in LEAP Model

Key assumptions deal with the demographic, economic and development indicators salvaged from multiple data sources and helps with the calculation. Some data is also inserted just as the information.

The key assumptions included in the model are

1- **GDP:**

   GDP is calculated as the product of per capita income and population and is taken to be around 5.5% [6].

2- **Population growth rate:**

   The population growth rate has been considered and the average of 3 years of growth has been taken to be around 2% [6].

3- **Income growth rate:**

   Income growth rate is taken as to be around 6.4% [6].

4.5 Development of Future Scenarios

With the increasing demand of electricity, it has become almost impossible to sustain the current system in the near future. The is important to put our direction and resources towards managing the current system by setting pathways for policy and modelling along with suggesting the new technologies and demand forecast using LEAP. Different scenarios for demand as well as supply has been developed to analyze the electricity conundrum. The assessment of the demand side scenarios is based on the electricity consumption and for the supply side scenarios different resources on the basis of their capital cost, OM cost, maximum availability, efficiency, fuel cost and environmental effects are suggested [9].

Table 9: Supply Side Input Data for all the Resources

Technology	**Lifetime (years)**	**Efficiency (%)**	**Availability (%)**	**Capital cost (Million US$/MW)**	**Fixed OM cost (US$/MW)**	**Variable OM cost (US$/MW)**
Hydro	40	86.5	53.82	2.71	20056	0.14
Natural gas	30	39.2	39.2	1.45	22248.2	5.40

Oil	30	44.9	83	1.37	21034	7.61
Wind	20	100	35	3.11	27236	0.05
Nuclear	40	34.7	70	3.51	97235	5.97
Solar	20	100	35	4	27236	0.05

4.6 Demand Side Scenarios

4.6.1 Reference Scenario (Ref):

The reference scenario which explains the business as usual situation and the Rawalpindi and Islamabad are divided or segregated into two separate regions Rawalpindi region and Islamabad region. In this scenario the residential growth rate is taken as the household growth rate in the activity level and the kwh of electricity consumption growth is taken as the final energy intensity growth rate. The Table 10 below shows the demand side data structure

Table 10: Demand Side Data Structure

Input data	**Value**
No. of units	2-3%
Electricity energy intensity	3-4%
Baseload powerplants	Hydro, Oil, Natural gas

4.6.2 Reference High scenario (Ref HI):

High value scenario is also developed to see the high-level peaks of the consumption. This scenario is developed by considering the idea that the use of the energy unfriendly devices may cause some increase in the demand of energy. The growth rate has been increased as per the reference scenario (Ref).

4.6.3 Reference Low scenario (Ref Low):

Similarly, low level scenario is developed to understand and observe the low-level peaks. This scenario is developed by considering that the use of the energy efficient devices in future may help reduce the energy demand. The growth rate has been lowered comparing to reference scenario (Ref).

4.7 Supply Side Scenarios

4.7.1 Ref Scenario (Ref):

This scenario follows the current government policies and plans. Present to near future data is included in this scenario. This scenario assumes that the future will follow the same trend structure as happened in the past without any changes in the policy. This scenario also emphasizes on the future resources of the electricity generation. This scenario will determine the outcome of the current system if we keep putting pressure on the existing system of electricity generation. The past trends include electricity generation technologies, efficiencies, transmission and distribution losses, the percentage share in the electricity generation, the fuel used, the installed plant capacity, the electricity consumption growth rate, the economic growth rate, the GHG emissions etc. The table below explains the input data for this scenario with almost 92% hydro, 1.25% natural gas and around 6,75% of oil contribution.

Table 11: Energy Contribution of the Resources for IESCO

Resources	Capacity (MW)
Hydro	2284
Diesel	31
Gas	165
Total	2480

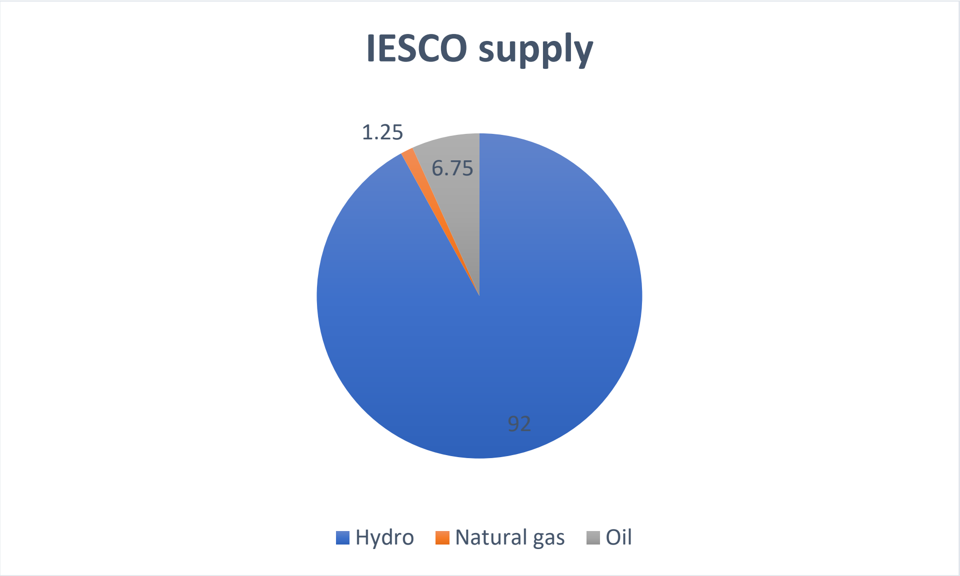

Figure 6: Percentage Share of Energy Contribution of Resources for IESCO

4.7.2 National Ratio Scenario (NAT):

This scenario follows the national energy ratios as our electricity production sources is from gas, diesel and hydro. As the sources of supply of electricity are different than that of the rest of the Pakistan so this scenario will split the electricity sources to the national energy mix ratios and will follow the same trends and ratios of electricity. In our scenario, almost 80% of the electricity is coming from the hydro and overall in Pakistan almost 30% of the electricity is derived from the hydro. So, this scenario will take some other sources like solar, wind and nuclear as well in order to provide a complete analysis of national ratios. So, according to the national ratios the oil share is around 30%, gas 33%, hydro 27%, nuclear 5% and 5% renewables (solar and wind) [10].

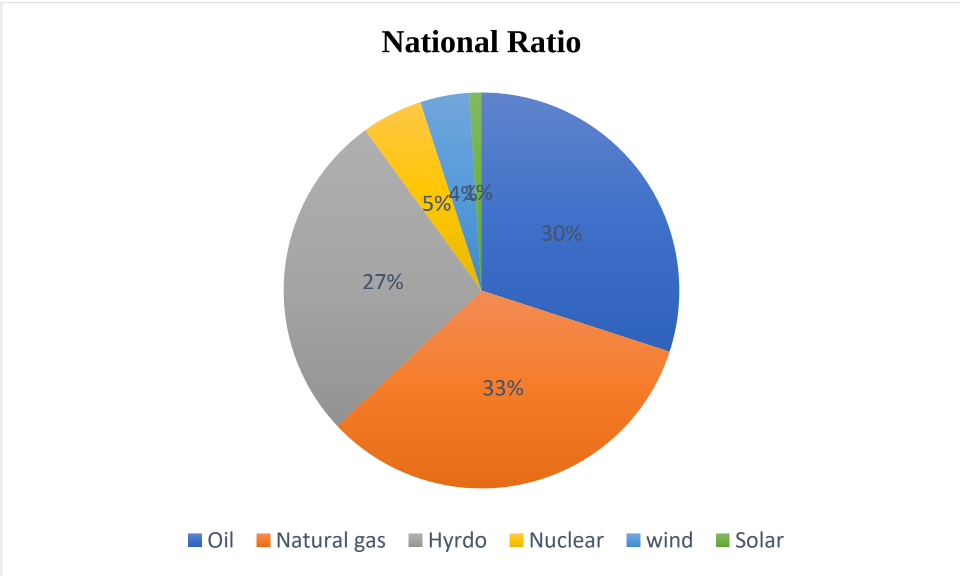

Figure 7 Percent Share of Resources in National Ratio

4.7.3 Renewable Scenario (REN):

This scenario will deal with the renewable energy resources and will include the hydro, solar, wind and nuclear. The overall gas and oil load have been transferred to the solar, wind and nuclear to observe the sustainability of the system through the renewable energy resources. The renewable is incorporated in the year 2022 in the system up till 2022 the existing oil and gas will be working on the renewable place. Also, the hydro potential has observed to be increased over time in the form of micro-hydro projects being the part of the system. The hydro power plants (HPP) added to the system over time could be observed from the table below [11].

Table 12 Added hydro power capacity over the years

Hydro Power Plants (HPP)	Year	Capacity (MW)
Gulpur HPP	2022	102
Kotli HPP	2026	102
Rajdhani HPP	2030	132
Sehra HPP	2038	130

The overall hydro capacity will be observed as in the table below

Table 13 Overall Added Hydro Capacity Over the Years

Resources	2016	2022	2026	2030	2038
Hydro	2284	2386	2488	2620	2750
Diesel	31	31	31	31	31
Gas	165	165	165	165	165
Total	2480	2582	2684	2816	2946

Summary

The comparison of different modeling tools have been conducted and LEAP has been chosen for the analysis due to its obvious and distinctive features compared to all the other models. The data structure has been analyzed for LEAP and it is observed that the validity of data is of supreme importance. Pakistan is a developing country and not much of the data is organized at national level or urban level. Data has been collected from different reports published by the institutions and IESCO headquarter has been visited to get the desired data. Data is then organized as per the LEAP requirements for both demand and supply side analysis. Key assumption has also been set in the form of population growth, GDP growth and Income growth for the analysis. Demand and transformation requirements of LEAP have been filled with the data. Supply side scenarios have been set as reference scenario (Ref), national ratio scenario (NAT) and renewable scenario (REN) and the data has been inserted as per requirements. Both econometric and end user approach have been employed for the electricity demand.

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Chapter 5

Result and Discussion

5.1 Demand Side Scenarios

5.1.1 Reference Scenario

LEAP is a helpful tool in analyzing the demand using custom set of branches. The final demand analysis includes the product of energy intensity and activity level at all branches. The useful energy demand analysis takes help from energy intensity, fuel share and efficiency of each branch. However, in this case we have calculated the final energy demand by sector wise electricity consumption of the Islamabad and Rawalpindi over the period of 2016 to 2050.

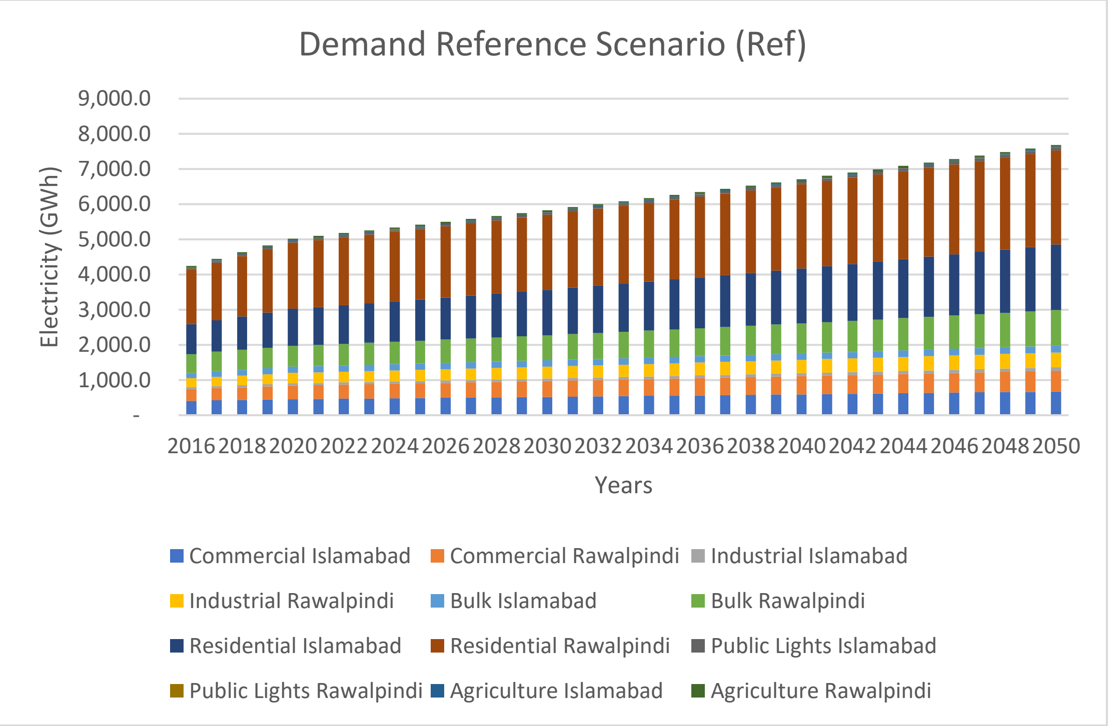

Figure 8: Overall Demand of Islamabad and Rawalpindi in Reference Scenario (Ref)

The total demand of all the sectors could be observed in Figure 8 and the demand seems to be increasing from 4200 GWh in 2016 to around 7800 GWh in 2050. There seems to be around 90% of increase in the electricity demand over the years which raises serious questions regarding the sustainability.

5.1.2 Commercial Islamabad and Rawalpindi

The figure explains the electricity demand of commercial sector of Islamabad and Rawalpindi. The demand seems to be increasing from 750 GWh in 2016 to 1300 GWh in 2050 which expresses a pretty extreme growth of around 90 %. It is important to understand that this growth in demand in only for commercial sector of Islamabad and Rawalpindi.

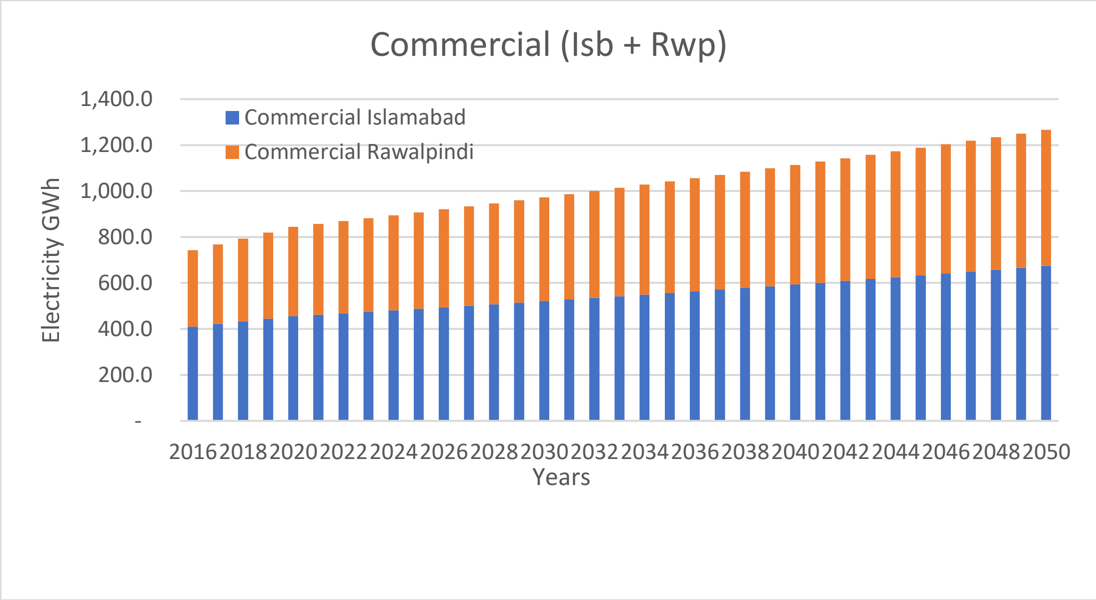

Figure 9: Overall Commercial Sector Demand for Islamabad and Rawalpindi

Now in order to see the separate demand growth we can see that the division 1 for the commercial sector of Islamabad (Figure 10) has the growth of almost around 70 % but in talk about the maturity it is also to be considered as if there is enough space for new commercial activities. F 6 has the most consumption followed by the Blue Area in division 1 with almost around 755 increased demand. Similarly, for division 2 (Figure 11) there is an increase in the I 9 and F8 areas and for division 3 (Figure 12) we can see a huge increase in the Bara kahu 1 due to the recent development of the region which paved way for commercial activities.

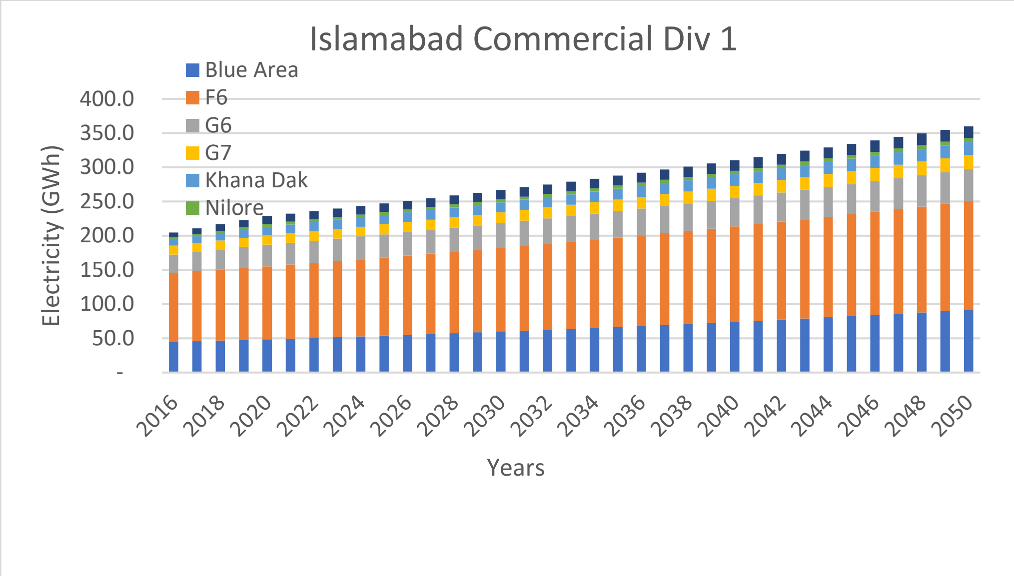

Figure 10:Commercial Islamabad Division 1

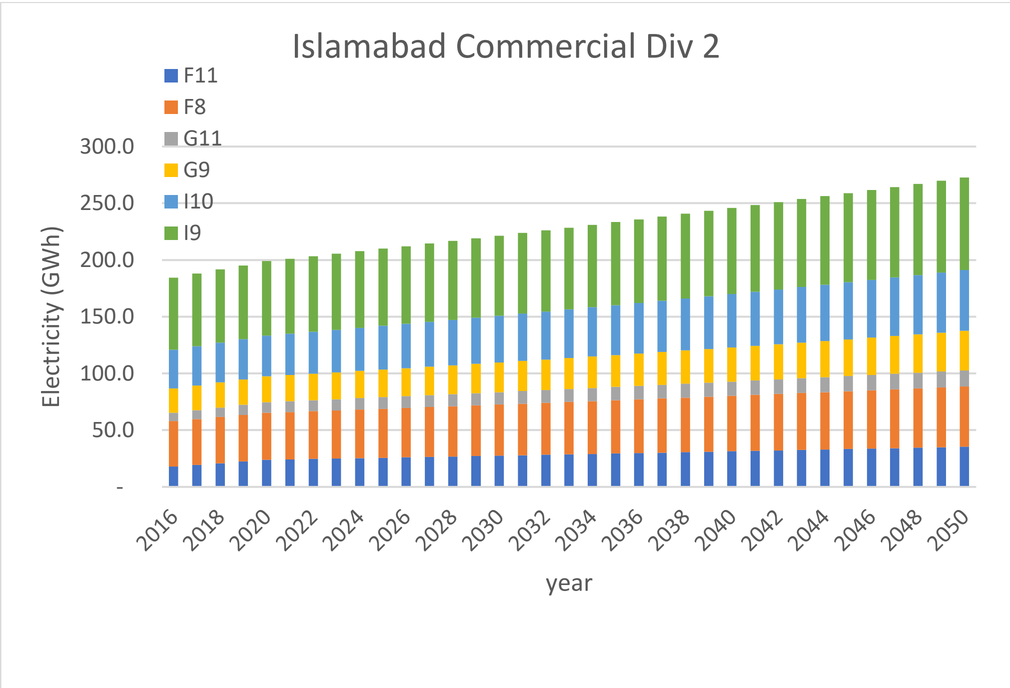

Figure 11: Commercial Islamabad Division 2

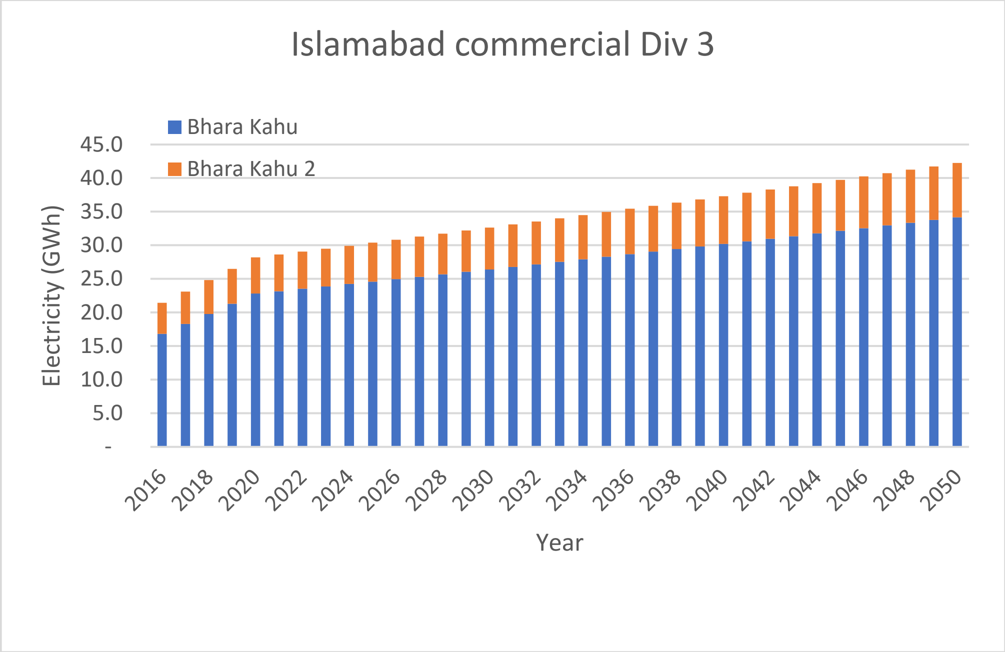

Figure 12: Commercial Islamabad Division 3

The commercial sector of Rawalpindi can be seen in the Figure 13, there is also a 100% growth in the demand of this region from 2016 to 2050 and there is an overall steady increase in the electricity demand in this region

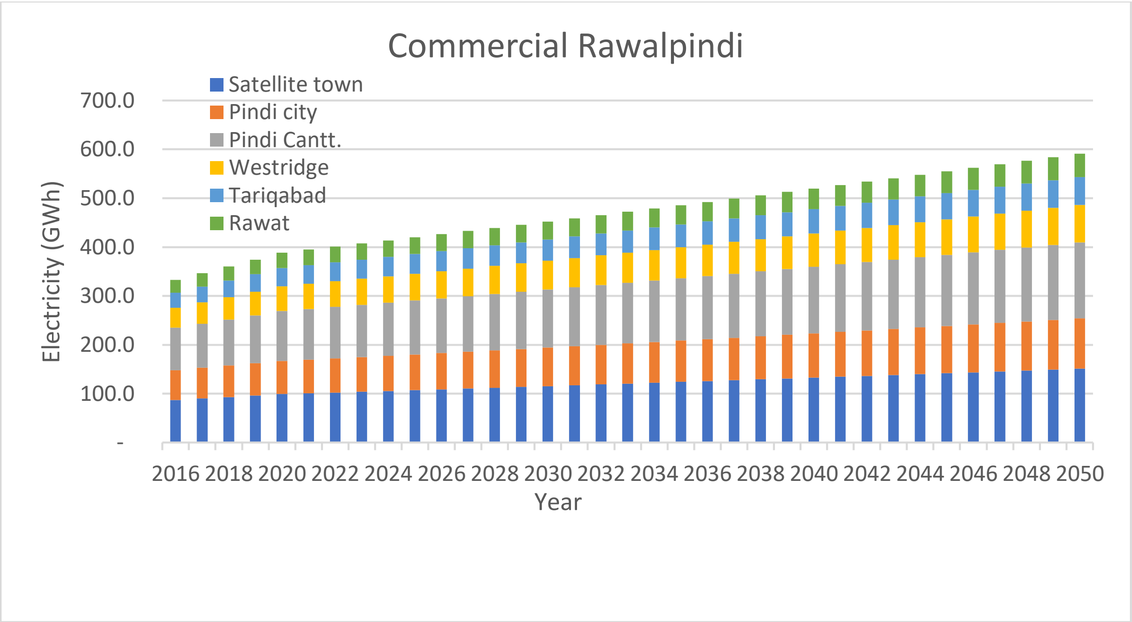

Figure 13: Commercial Rawalpindi

5.1.3 Overall Industrial Islamabad and Rawalpindi

The industrial demand for both Islamabad and Rawalpindi has seem to be increasing from 300GWh in 2016 to around 520 GWh in 2050 which shows the increase of around 80% as observed in the Figure 14. It is imperative to note that we also have analyzed the maturity of the growth in demand. The data is presenting the mature future projection.

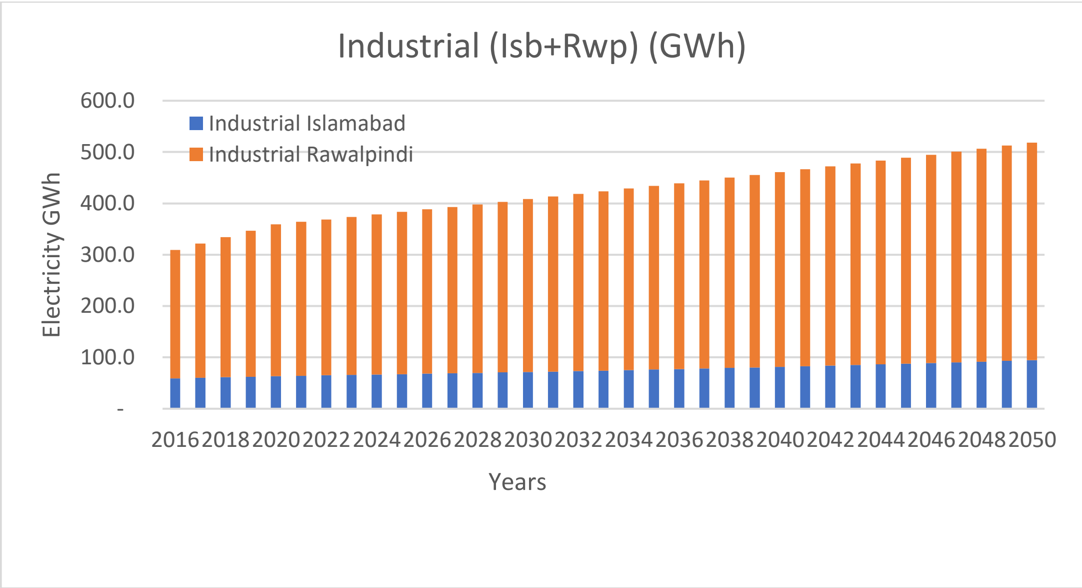

Figure 14: Overall Industrial demand for Islamabad and Rawalpindi

The division wise industrial consumption has been also analyzed. In division 1 (Figure 15) it could be observed that the G 6 sector seems to have been growing fast in terms of industrial consumption and there is almost more than 100% increase in demand by 2050. The division 2 (Figure 16) shows quite a steady growth in the industrial sector as this division is mostly occupied by the residential or commercial sector and there is not much room for the industrial growth but still there is a steady growth in the demand of electricity over the years. The division 3 (Figure 17) including the areas of Bara kahu and Bara kahu 2 there is not much increase in the industrial demand as these areas are not much developed and there are not any worthwhile industrial projects.

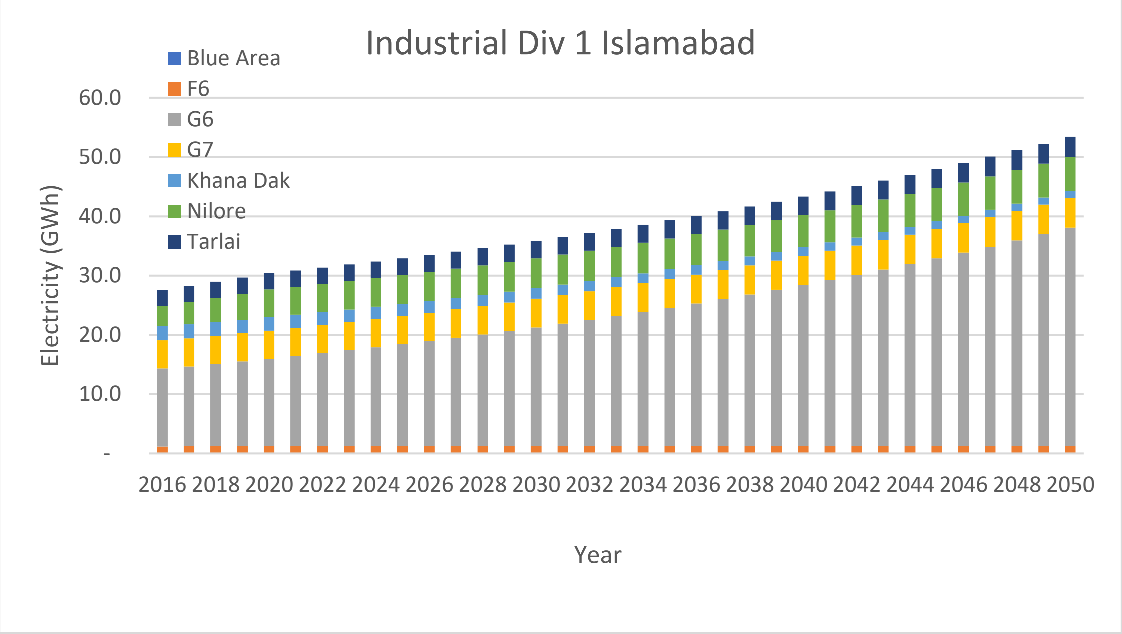

Figure 15: Industrial Islamabad Division 1

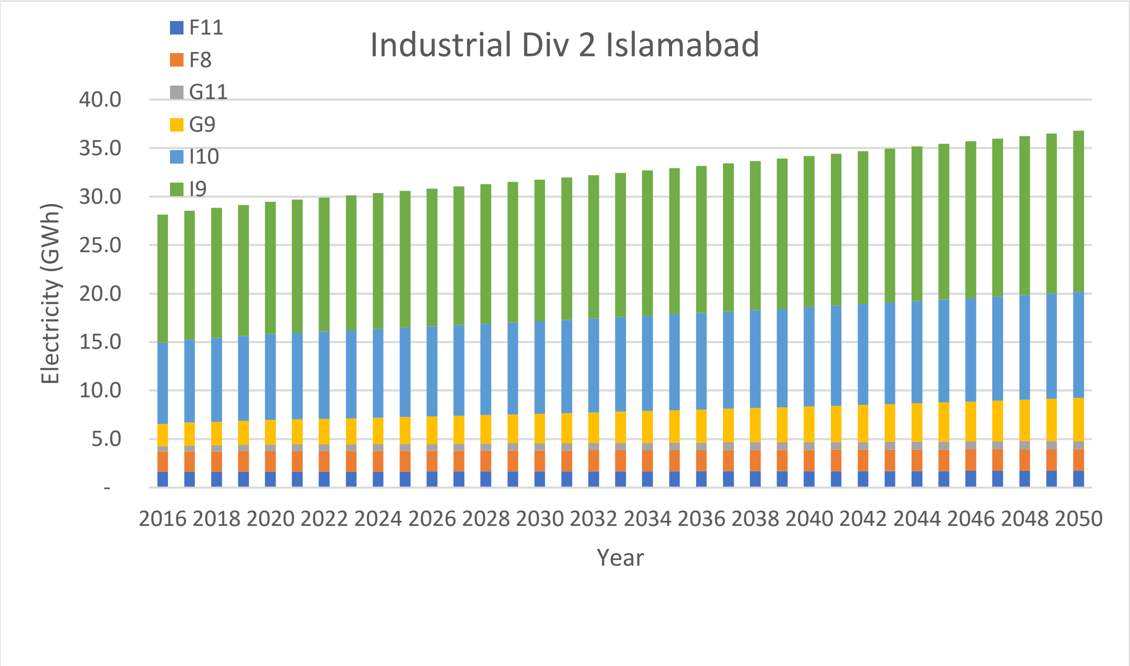

Figure 16: Industrial Islamabad Division 2

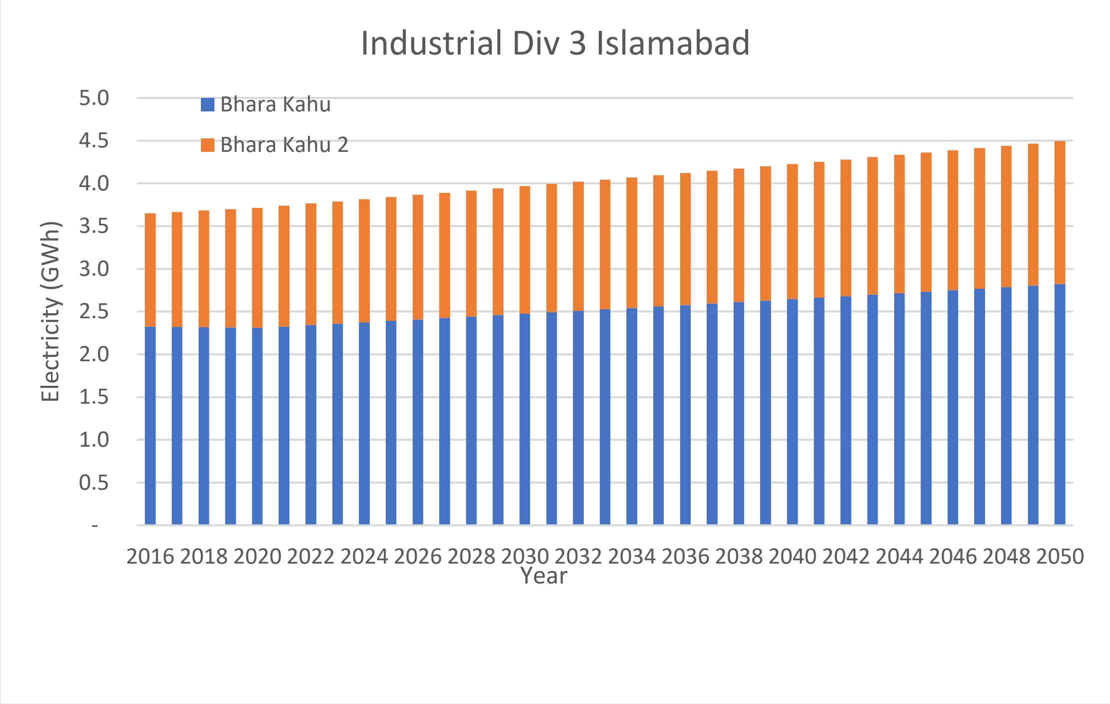

Figure 17: Industrial Islamabad Division 3

Now moving towards the Rawalpindi industrial sector (Figure 18), we could find a great degree of increase with already a huge electricity demand. There is quite a huge demand in the industrial sector of this area and the demand seems to be increasing from around 250 GWh in 2016 to almost 450 GWh with the increase of around 80 %.

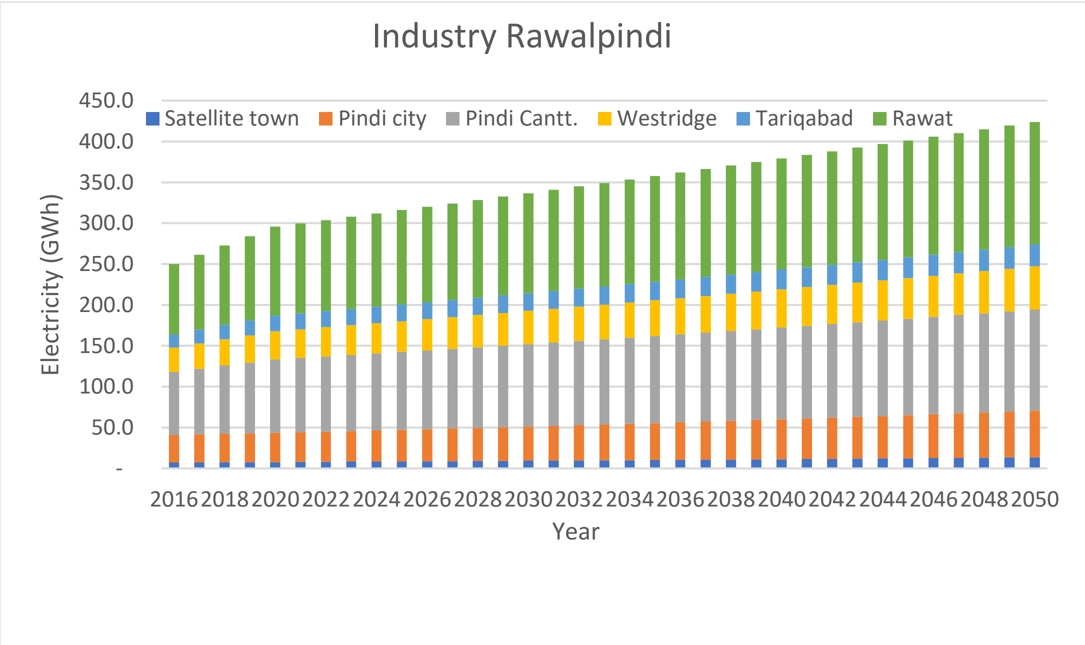

Figure 18: Industrial Rawalpindi

5.1.4 Residential sector in Islamabad and Rawalpindi

Now moving towards the residential sectors of Islamabad and Rawalpindi it could be observed that the demand of the residential sector has been increased from 2900 GWh in 2016 to around 4500 GWh in 2050. The total increase in the demand of residential sector is around 50% but it is important to understand that the potential of the residential sector demand needs to be understood in terms of number of units or consumers and then the growth rate. The overall demand for residential sector could be seen in the Figure 19.

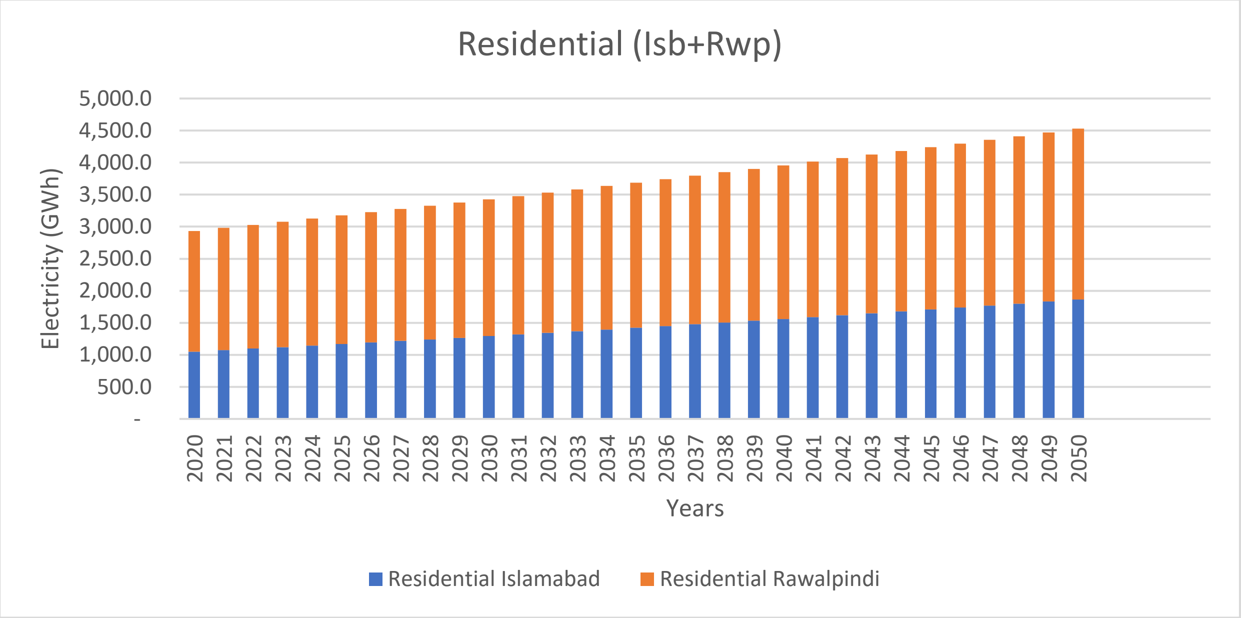

Figure 19: Overall Residential Demand for Islamabad and Rawalpindi

Now in order to see the separate demand growth we can see that the division 1 (Figure 20) for the residential sector of Islamabad has the growth of almost around 120% but in talk about the maturity it is also to be considered as if there is enough space for new commercial activities. The F 6 has the most consumption followed by the G6 in division 1 with almost around 500 GWh increased demand. Similarly, for division 2 (Figure 21) there is an increase in the F11 and G11 areas and there is around 100% increase in demand over the years and for division 3 (Figure 22) we can see a huge increase in the Bara kahu 1 due to the recent development of the region and the population increase around the area so there is a massive increase in demand over the years.

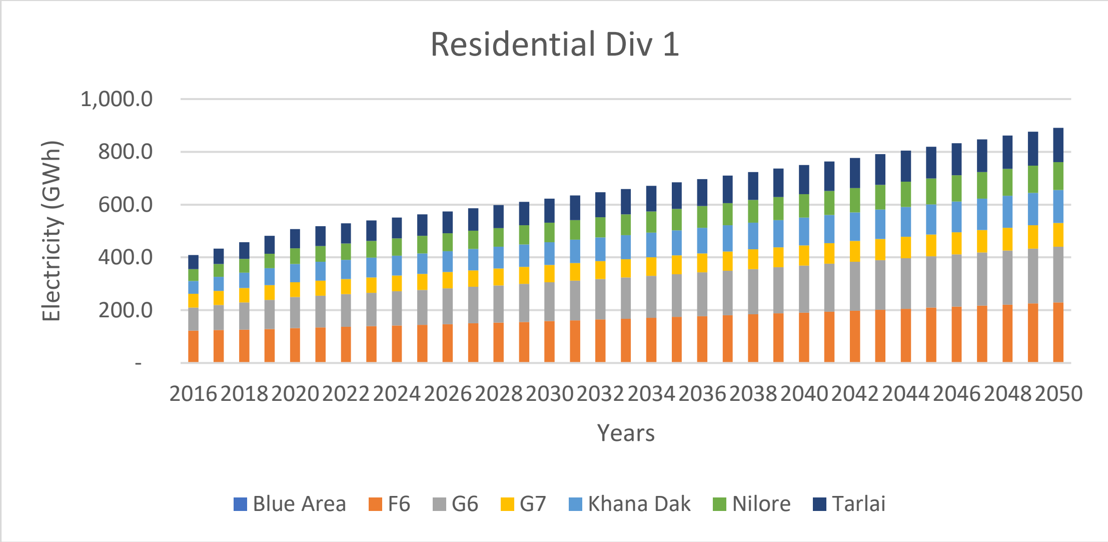

Figure 20: Residential Islamabad Division 1

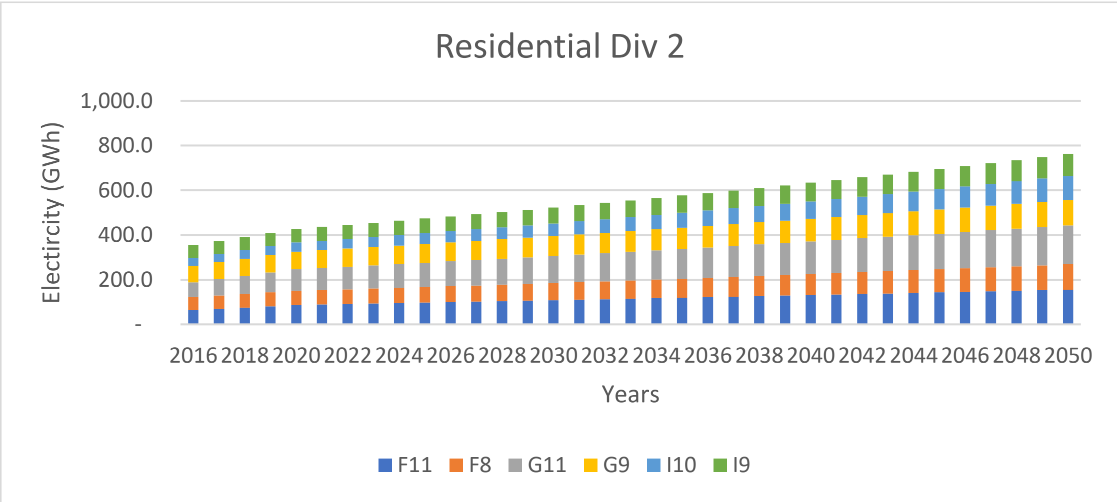

Figure 21: Residential Islamabad Division 2

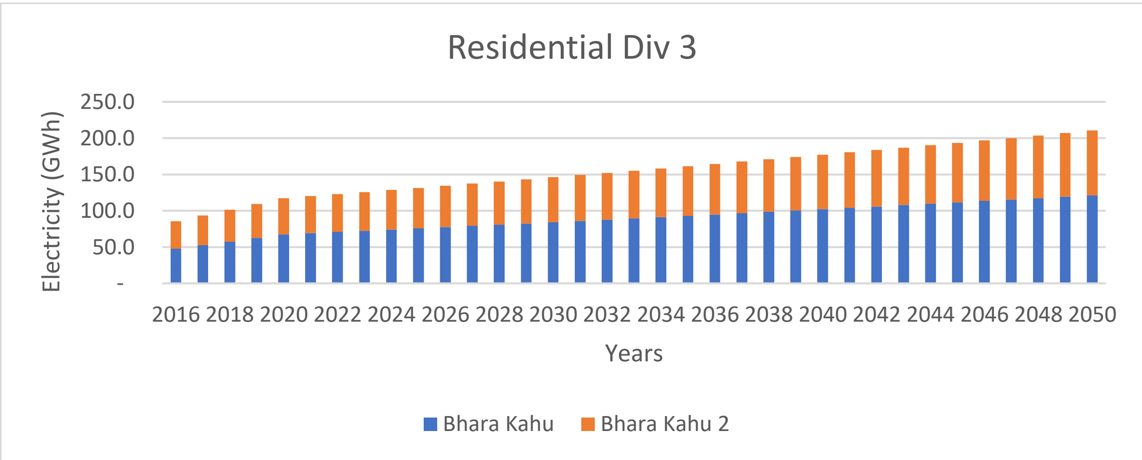

Figure 22: Residential Islamabad Division 3

Now moving towards the Rawalpindi residential sector, we could find a great degree of increase with already a huge electricity demand. There is quite a huge demand in the residential sector of this area and the demand seems to be increasing from around 1600 GWh in 2016 to almost 2700 GWh with the increase of around 80 %. The Figure 23 explains the residential sector demand for Rawalpindi.

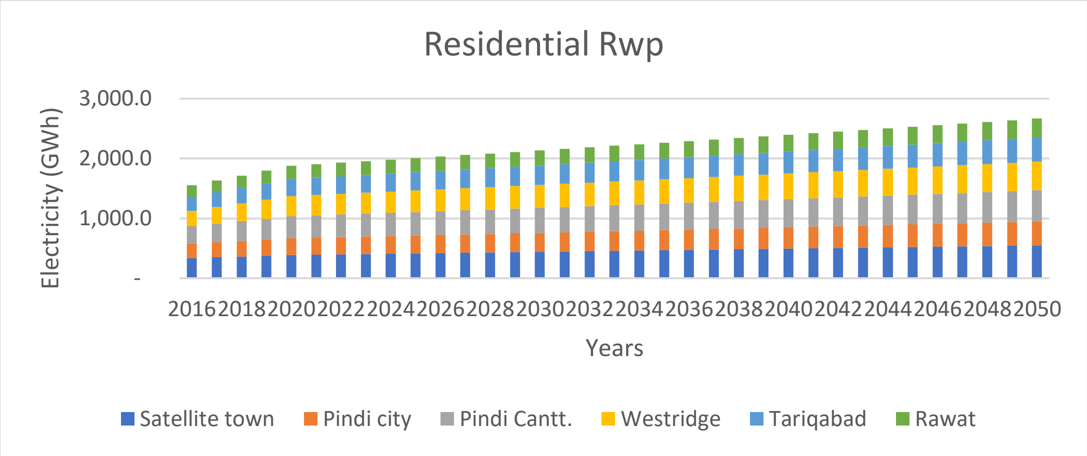

Figure 23: Residential Rawalpindi

5.1.5 Bulk Islamabad and Rawalpindi

The bulk includes the government institutes and sectors. The increase in the demand for this area is pretty high as well but it is not so sure to predict the demand of this area. As the bulk sector demand seems to be around 680 GWh in 2016 to 1200 GWh in 2050. It is still hard to tell about the modeling of this sector as there does not seem to be much room for the growth in the government institutes.

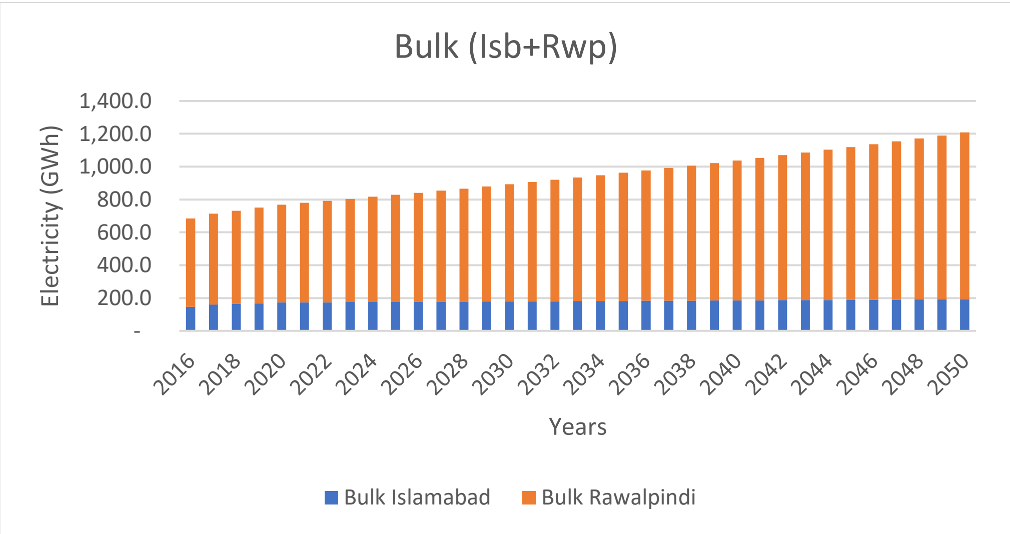

Figure 24: Overall Bulk Demand for Islamabad and Rawalpindi

5.1.6 Public lights:

This area includes the demand of public lights. As we are discussing the Islamabad and Rawalpindi mainly, so the overall public light demand is analyzed. There is a great use of public lights in the Islamabad region and also there is an increase in the energy demand by around 80%. However, the government is trying to implement the solar panels for the public lights in Islamabad and Rawalpindi which will hopefully help in getting rid of the public lights demand in coming years. The Figure 25 below explains the public lights situation.

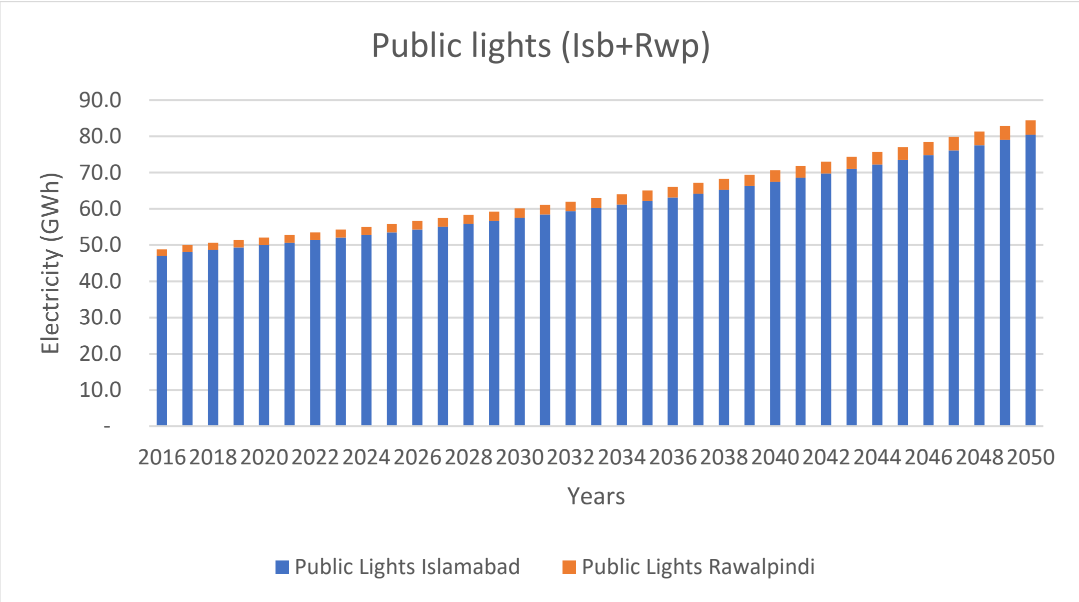

Figure 25 Overall Demand for Public Lights Islamabad and Rawalpindi

5.1.7 Agriculture:

Islamabad and Rawalpindi do not have much of the agriculture potential because of the urbanization. There is not enough room for the agriculture in the city. However, some of the areas of Islamabad and Rawalpindi do have the agriculture potential as observed in the Figure 2.

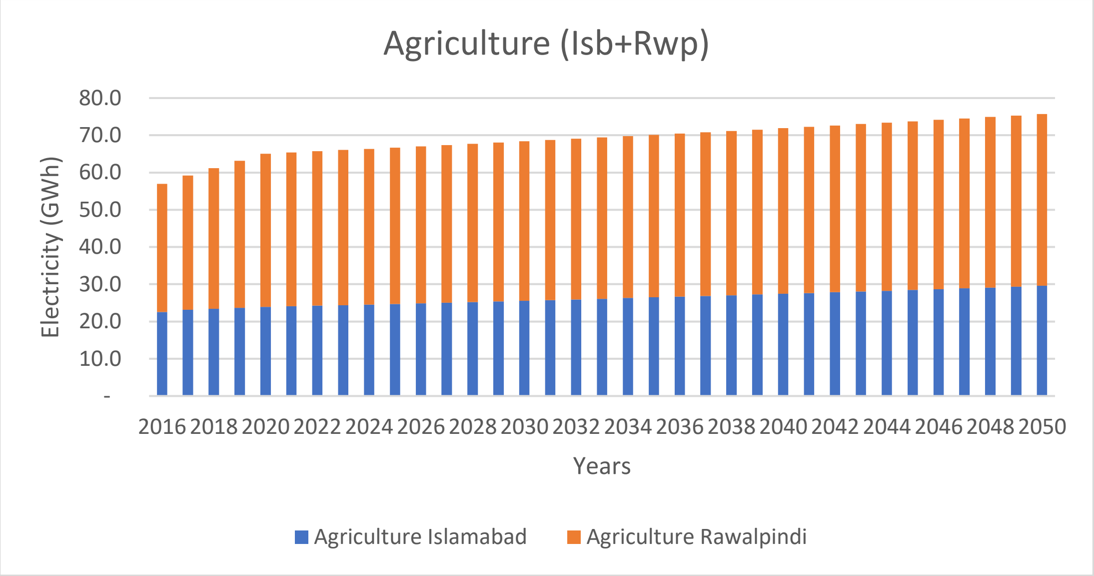

Figure 26 Overall Agriculture Demand Islamabad and Rawalpindi

5.1.8 Comparing results with the IESCO forecast:

Islamabad Electric Supply Company (IESCO) did an analysis on the demand forecast for all the regions under the IESCO including the Attock, Jhelum and AJK regions, For the period 2016-17 to 2026-27, annual average compound growth rate of energy sale, peak demand and energy purchased will be 5.07%, 5.26% and 5.04% respectively for all the sectors. This analysis does not provide comprehensive results because of the compound growth rate and no supply side scenarios have been conducted to balance the demand (Figure 27).

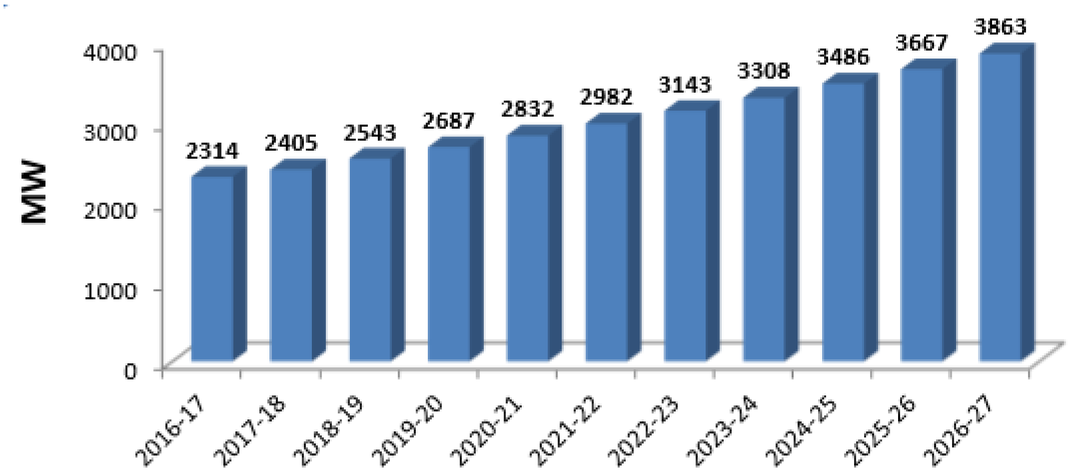

Figure 27 IESCO Demand forecast from 2016 to 2027

These results may seem somewhat different than our results because of these results include the whole IESCO region. No supply side development and analysis has been conducted in this forecast.

Our results only constitute the Islamabad and Rawalpindi region and it is also to be noted that we analyzed all the sectors with different growth rates as per the historical data of the sectors. Our research also included multiple scenarios to compare and contrast the results along with the alternative sources like renewables incorporation into the system. As it can be observed for the figure that our results explain the demand of all the sectors separately and comprehensively. The supply side scenarios have also been discussed with penetration of renewables into the system.

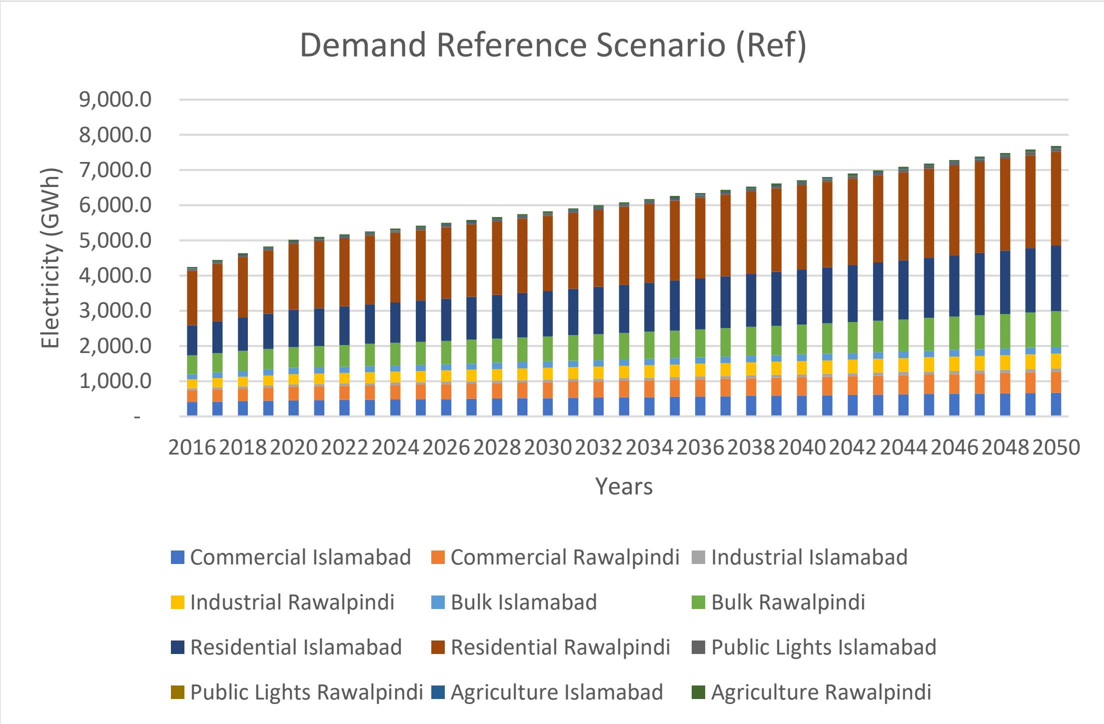

Figure 28 Overall Reference Scenario (Ref) Demand for Islamabad and Rawalpindi

Reference high scenario (Ref HI):

This scenario is developed to see the high-level peaks of the electricity consumption. This scenario is developed by considering the idea that the use of the energy unfriendly devices may cause some increase in the demand of energy. It is however observed by increasing the number of units and electricity consumption of all the sectors. The final demand seems to be increased by more than 100% in this scenario which is due to the poor efficiency of the devices causing the overall demand to extend over 100%.

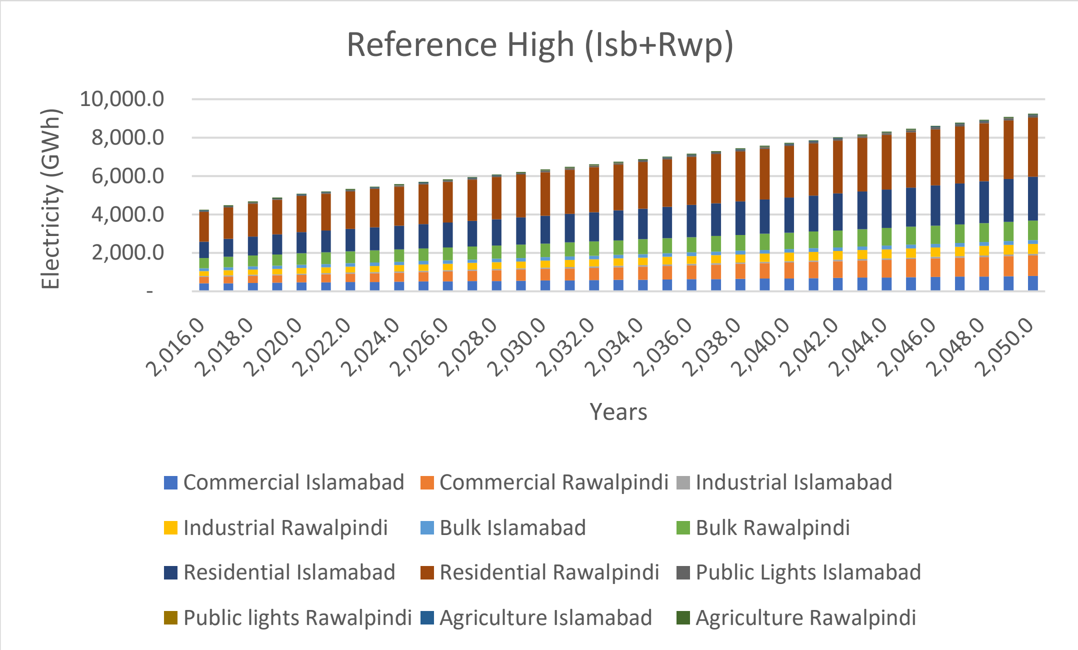

Figure 29 Overall High-Level Peak of Reference Scenario

Reference low scenario (Ref Low):

This scenario deals with the low-level peak of the energy consumption and is influenced by the idea that by improving the efficiency of the devices a lot of energy could be saved. This scenario is developed by considering that the use of the energy efficient devices in future may help reduce the energy demand.

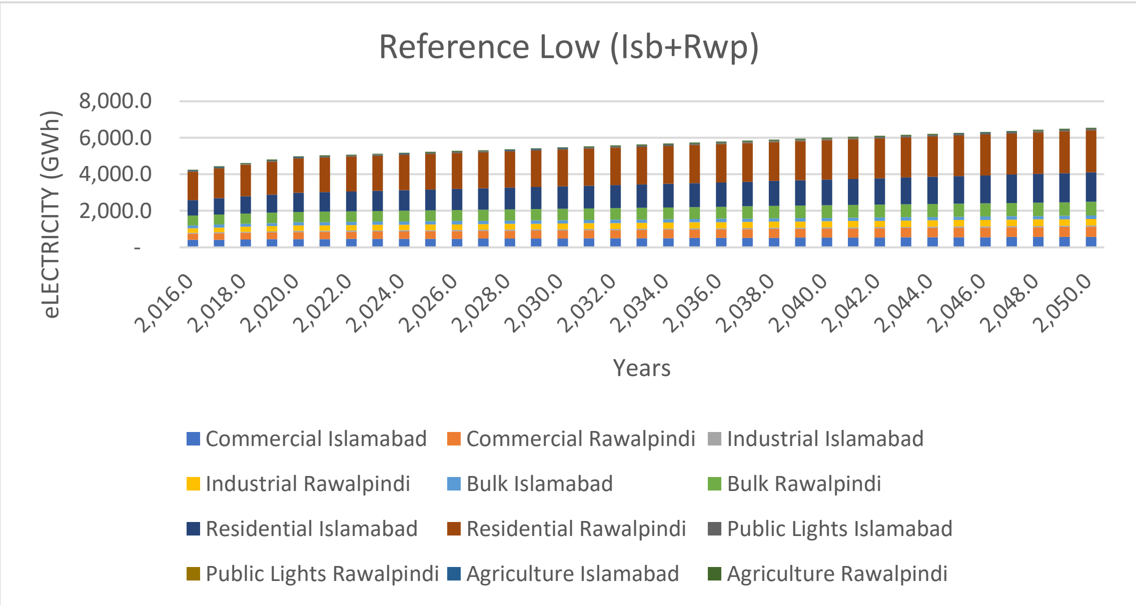

Figure 30 Overall Low-Level Peak of Reference Scenario

5.2 Supply Side:

5.2.1 Reference Scenario (Ref)

The reference scenario (Ref) includes the supply side data for all the sectors. The overall data of Islamabad and Rawalpindi is divided into 6 sectors including the residential, commercial, industrial, agriculture, bulk and public lights [1]. All the sectors are included to provide a legitimate supply side projection as the supply is dealing with all the sectors of the areas. The supply side addition of micro-hydro projects in MWh with the year based addition could be observed in the table below [2].

Table 14: Hydro Added capacity over Time

Sources	2016	2022	2026	2030	2038
Hydro	2284	2386	2488	2620	2750
Diesel	31	31	31	31	31
Gas	165	165	165	165	165
Total	2480	2582	2684	2816	2946

There is no addition of energy over the years for diesel and gas, but we can see the increase in the hydro potential over the years as the government has already initiated some projects and some projects are still to be initiated. Figure 31 explains the supply side reference scenario (Ref).

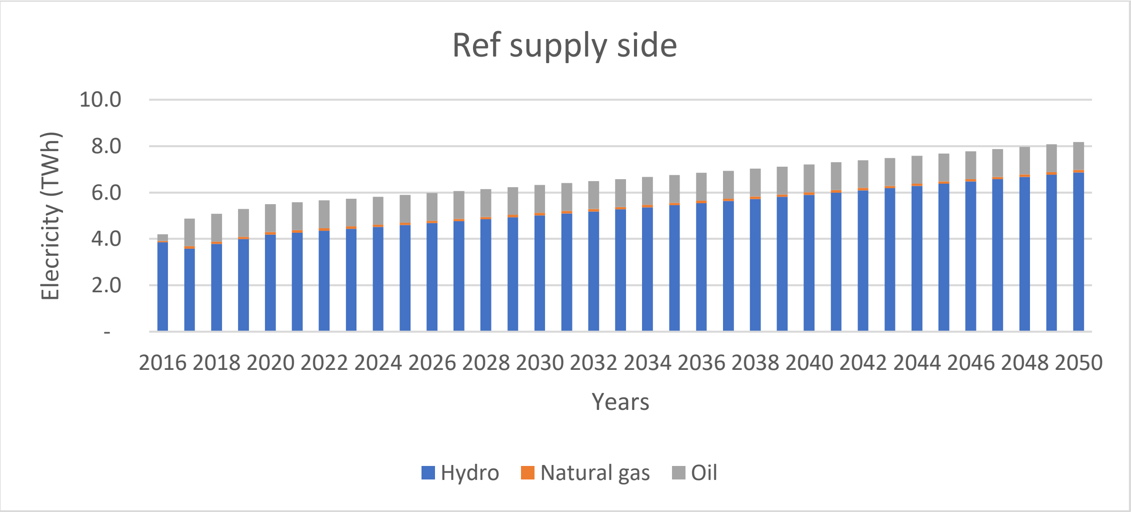

Figure 31: Supply Side of Reference Scenario

5.2.2 National Ratio Scenario (NAT)

National ratio scenario deals with the percentage share of the energy as per the overall electricity distribution throughout the country. It is helpful in terms of varying policy or in terms of understanding the scenario as per different policy paradigms for different areas.

We have found the upcoming projects that will add electricity to the system. Our supply being the 2480 MWh in 2016 and 2946 MWh by 2038 as per the current projects under construction. Now we can simply split both the 2016 electricity supply as well as 2038 electricity supply which seems to have been the case till 2050.

The national ratio distributes electricity as the 30% contribution from the oil sector, 33% contribution from the gas sector, 27% hydro, 5% renewable (solar and wind) and 5% from nuclear energy source [3] and the results are explained in the Figure 32.

Table 15: Distribution of Resources as per National Energy Mix

Years	Supply	Oil (30%)	Gas (33%)	Hydro (27%)	Renewables (5%)	Nuclear (5%)
2016	2480	744	818.4	669.6	124	124
2050	2946	883.8	972.18	795.42	147.3	147.3

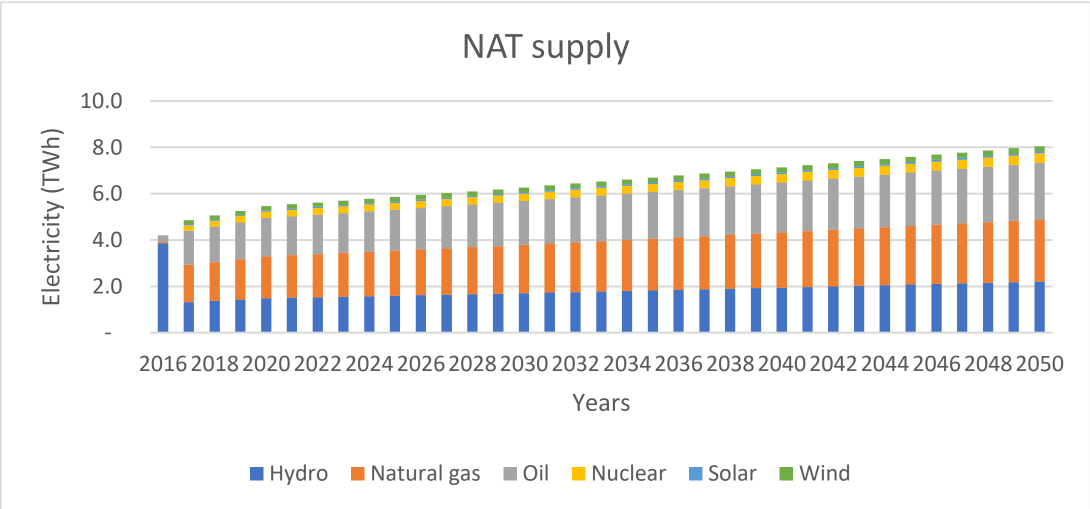

Figure 32: National Ratio Supply Side Scenario

5.2.3 Renewables Scenario

The renewable supply side scenario only deals with the renewable energy supply to the system. The oil and gas supply have been transferred to the solar, wind and nuclear energy to observe the difference that it creates. The oil contribution being the 31 MWh and the gas contribution being the 165 has been simply transferred to the Solar and wind and nuclear energy. We simply assumed as if we shift the supply from oil and gas to these renewables starting from 2022. Nuclear is been provided with the 5 MWh, 150 MWh has been provided to the solar due to high potential and 65 MWh has been put onto the wind energy. Figure 33 explains the Renewable Supply Side Scenario (REN).

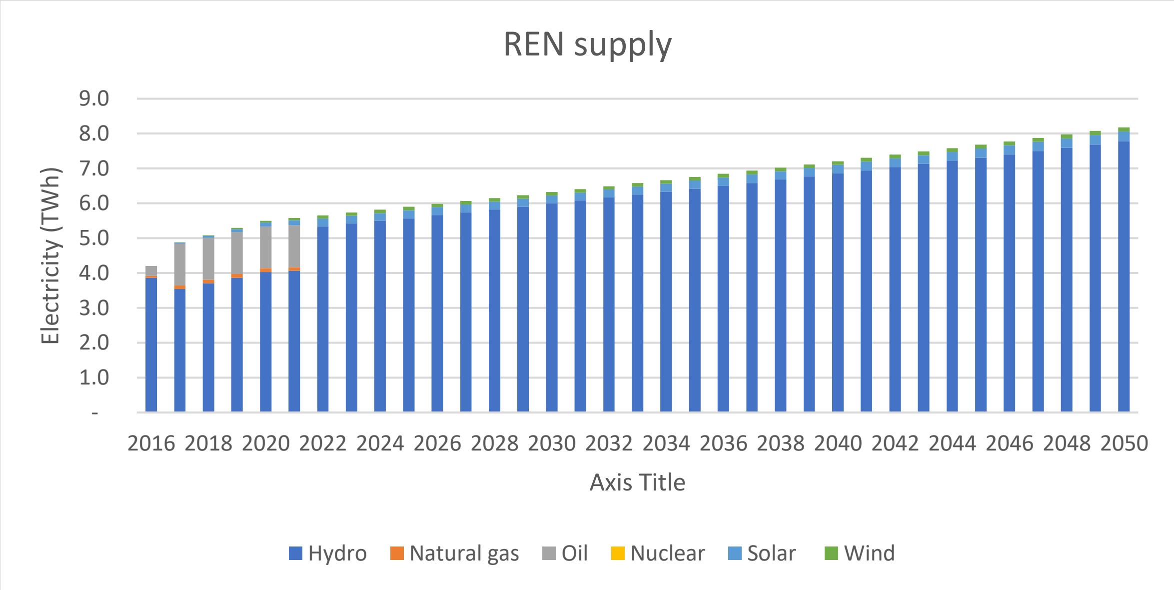

Figure 33: Renewable Supply Side Scenario (REN)

5.3 Environmental Analysis:

The environmental analysis explains the major threat to the environment under current circumstances. The climate change and global warming are the major environmental issues which are majorly caused by GHG emissions. International community has contributed to the clean environment regulation in the form of Kyoto protocol which imposed sanctions or tax on GHG emitters [4]. The Paris agreement has recently been introduced and as per the updated GHG inventory, the total emission of GHGs in Pakistan in the year 2012 has been estimated to be about 0.8% of the global GHG emissions and also on per capita basis, Pakistan stand at 135th place in the world ranking of the countries on the basis of their per capita GHG emissions [5].

5.3.1 Comparison of emissions for all scenarios:

Reference (Ref) vs National Ratio (NAT) scenario:

The emission increase from around 800 thousand metric tons of CO_2 emissions to 3000 thousand metric tons of emissions which emphasizes on the fact that a lot hydro potential with no emission is been switched to the oil and natural gas which comes with the 4 times increase in the environmental emissions. Also, the national ratio scenario is more expensive as the operational cost of both the oil and natural gas is way too high to effectively utilize these sources in the long run. The Figure 34 explains the emission analysis.

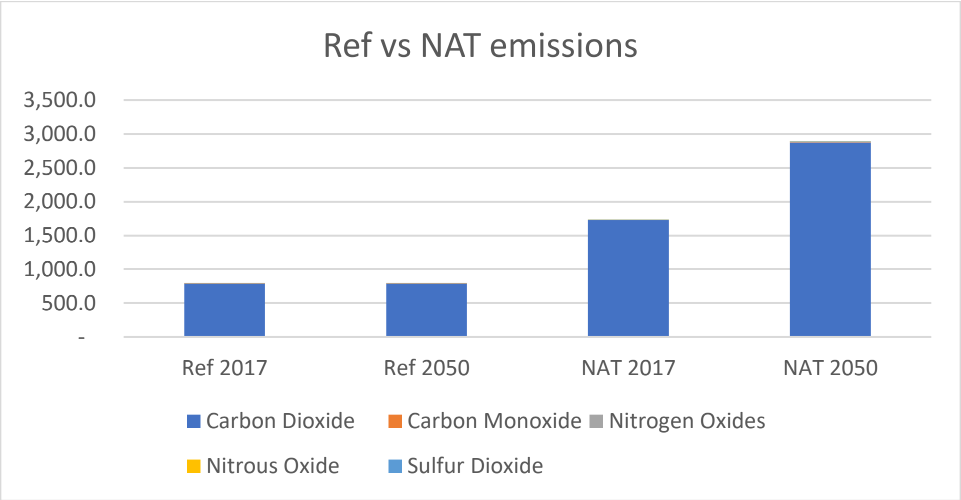

Figure 34 Reference (Ref) vs national ratio (NAT) emission analysis

Reference (Ref) vs Renewable Scenario (REN):

. This comparison will lead to the avoidance of the emissions observed in the reference scenario (800 thousand metric tons of CO_2 emissions) as observed in the Figure 8. This comparison will also help understand the smart city concept as the renewable scenario helps with not only the effective production of electricity but also fulfilling the Paris agreement requirements. As per the updated GHG inventory, the total emission of GHGs in Pakistan in the year 2012 has been estimated to be about 0.8% of the global GHG emissions and also on per capita basis, Pakistan stand at 135^{th} place in the world ranking of the countries on the basis of their per capita GHG emissions. Renewable scenario will also be a way forward towards the vision 2025 of

Pakistan energy security policy. Figure 35 explains the reference (Ref) vs Renewable (REN) scenario emission analysis.

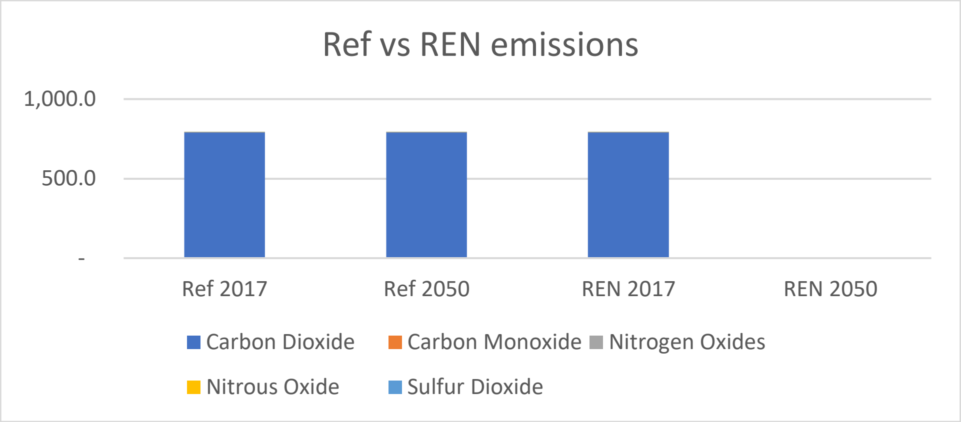

Figure 35 Reference (Ref) vs Renewable emission analysis

Summary

The results are discussed in this chapter as this is the main part of the thesis. The results are analyzed for all the regions or division of Islamabad and Rawalpindi separately like division 1, division 2 and Bara Kahu division of Islamabad and the Rawalpindi division. Then the result for all the sectors like residential, commercial, industrial, agriculture, bulk and public lights have been then combined and analyzed for both Islamabad and Rawalpindi. The scenario for demand side analysis is the reference scenario (Ref) and demand has been observed from 2016 to 2050. On supply side three scenarios have been analyzed like the reference scenario (Ref), national ratio scenario (NAT) and Renewable scenario (REN). In the reference scenario the planning and policies of the government have been implemented. The national ratio scenario (NAT) is distributing the demand by the division of the sources as per the national mix of all the sources like oil, gas, hydro, and renewables. The renewable scenario deals only with the renewable energy supply and this scenario is built by replacing the oil and gas supply of the reference scenario with the renewables like solar, wind and nuclear. It is observed that renewable scenario is the most efficient scenario as there are less emissions and requirements compared to national ratio scenario. Emission analysis has also been conducted and the major GHG gas CO_2 is observed to be highest in the national ratio scenario and no emissions in renewable scenario.

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Chapter 6
Conclusion and Future Recommendations

This research analyzed the urban electricity planning for Islamabad and Rawalpindi regions using the LEAP (long range energy alternative planning). Both econometric and end user approach has been applied for this bottom up energy model. The total demand and supply of electricity has been forecasted. The demand side scenarios include the reference scenario (Ref) which is also the business as usual scenario along with the reference high (Ref HI) and reference low (Ref Low) scenarios explaining the high- and low-level peaks respectively. The supply side three different scenarios such as Reference scenario (Ref), National ratio scenario (NAT) and Renewable scenario (REN) have been assessed. The overall results explain the electricity consumption and also provide the solution towards the sustainable future. All the sectors such as residential, commercial, industrial, agriculture, bulk and public light of Islamabad and Rawalpindi are included in this research. The results of the analysis could be summarized as follow:

Residential sectors of both Islamabad and Rawalpindi are the one accountable for the major electricity demand. One of the fundamental reasons is the urbanization and expansion of cities as there is almost negligible space for the agriculture sector in this region. The demand of this sector seems to be increasing up to 50% by 2050 which explains the further expansion of the cities.

The most suitable scenario is the renewable scenario as the renewables once installed will be working for more than 30-40 years. This will provide the sustainability in terms of electricity consumption.

National ratio scenario is not the suitable scenario because the major sources of national ratio scenarios are oil and gas which contribute to almost 60% of the total national mix in the electricity production and are not suitable in the long run. This study will also help provide an insight towards the urban planning as to how exploiting the renewable potential could help us get rid of the electricity production from oil and gas.

Environmental concerns are one of the fundamental concerns of the modern as the global warming along with the urbanization has already destroyed the natural habitat and ways of living. The most suitable scenario as per the environmental analysis is the renewable scenario (REN) as there are no emissions at all in this scenario and national ratio (NAT) has the highest of emissions due to major fuels being gas and oil.

This study recommends that the government should facilitate the metropolitan cities in terms of their increasing demand. As the study explains that there is almost no or little concern over the futuristic demand of electricity and no policy has ever been devised at the urban level which further fan the flames. The major emphasizes should be on the proper policy and planning of all the metropolitan cities so that a comprehensive approach could be developed for sustainable future.

Annexure

Electricity consumption modelling in industrial and commercial sector of Islamabad and Rawalpindi

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Electricity has been the major issue in Pakistan for last 2 decades and the industrial and commercial sectors have suffered the most from all the energy conundrum. The primary purpose of this study is to understand the nature of electricity consumption modelling in the industrial as well as commercial sector of Islamabad and Rawalpindi. This study will emphasize the electricity modeling of industrial sector of Islamabad and Rawalpindi using Long range energy alternative planning (LEAP). LEAP is an effective tool that is used for modelling over the long span of time. Electricity consumption demand is observed, and multiple scenarios have been discussed over the span of around 30 years and the result of these scenarios led us to formulate a strategy towards the effective energy policy. These scenarios compelled us to understand the future concerns that could help formulate policies for sustainable development in industrial and commercial sector of Islamabad and Rawalpindi.

Keywords: LEAP, Energy modelling, Electricity consumption, Sector based analysis, Islamabad and Rawalpindi

1. Introduction:

Energy is the basic commodity of life and there is lot of talk about the energy policy over the last few years. The major issue regarding the energy is the sustainability as with the exponential rise in the world's population it has become almost impossible to create a balance between the energy demand and the population growth. Energy is the key player in providing the sustainability to the economy by helping all the sectors like domestic, commercial, agriculture and industrial. There is great degree of efforts globally to develop a sustainable economic system that could contribute towards the efficient energy model [1]. A lot of research has been conducted globally on the regional as well as sectorial based consumption modeling like in India, China, Japan, Indonesia and Korea [2-6]. All These researches also emphasize on the regional sources available for the electricity consumption.

Pakistan is facing a drastic energy situation over the last two decades. The main reason of this imbalance is the meagre economic conditions along with the poor policy as well as infrastructure and use of oil and gas for electricity production instead of paying attention to the renewable energy resources. Pakistan is blessed with high potential of hydro energy but still due to lack of infrastructure and up-dation of already existing system there is a shortage of around 4 to 5 GW from the last 2 decades [7]. The energy demand of Pakistan has reached over 21,200 MW while the supply is only 16,548 MW [8]. Average energy per capita for Pakistan is 405 kWh, which is pretty low [9]. The domestic sector only has gone over to the increased electricity consumption from the 22.8 TWh in 2000 to 36.1TWh in 2011 because of the urbanization and upgradation of standards of living [10].

The major emphasis is on the sectoral based electricity modeling as different sectors have different growth rate and different energy requirements. The major sectors contributing towards the electricity consumption are domestic, commercia, industrial, agriculture, bulk and public lights. The major consumption is observed to be in the domestic or residential sector, but commercial and industrial sector are of supreme importance as well because these 2 sectors also help built the economy. The major emphasis of this research is on the sectoral based electricity modeling of the commercial and industrial sectors of Islamabad and Rawalpindi.

2. Islamabad and Rawalpindi electricity situation:

Islamabad and Rawalpindi do fall under the Islamabad Electric Supply Company (IESCO). IESCO was formed in 1998 to take over the responsibilities of WAPDA's division named as Islamabad Area Electricity Board (AEB). The primary purpose of the IESCO is to sell power in the areas from Attock to Jhelum including the river Indus to river Neelum in Kashmir [11]. The total number of industrial and commercial units working under the IESCO are around 20,000 and 370,000 respectively. These units include the overall industrial and commercial units under the IESCO. We are only analyzing the situation in Rawalpindi and Islamabad. The number of consumers for all the sectors could be seen in the table below [11].

Table 16 No. of consumers data

Sector	No of consumers (million)
Domestic	2.27
Commercial	0.37
Industrial	0.02
Agriculture	0.008

Islamabad and Rawalpindi have huge number of industries. The electricity or energy consumption as well as distribution management is a major problem in Islamabad and Rawalpindi. Rawalpindi along with Islamabad share the same burden and fate regarding energy management. Both commercial and industrial activities are one of the fundamental electricity consumers in Islamabad and Rawalpindi. Industrial estate Islamabad (IEI) was established in early sixties. It covers more than 250 industries. The Capital Development Authority (CDA) is managing the Industrial Estate Islamabad [12]. Islamabad IEI was isolated from residential area through a buffer zone, but now residential area has developed very close to it flour mills, oil and ghee marble cutting and Islamabad IEI was isolated from residential area to the south and west due to elimination of buffer zone by CDA [12].

Now the focus of our discussion is going to be on the energy consumption modelling of Industrial sector of Islamabad and Rawalpindi. If we consider the specific energy system analysis and integrated level planning needs of Islamabad Industry leading to propose a model for energy efficient consumption and conservation measures. In either case the poor intellectual base, poor administrative setups, deficiencies of resources and infrastructure and above all the inadequate and unreliable data present potential barriers. However, with all these limitations the model based integrated energy design allow studying of multiple scenario alternatives; which can compensate for the imprecise and poor-quality data. The significance of this research is based on the efficient consumption behavior in industrial and commercial sectors which will reduce the energy requirement and to understand the future prospects of these sectors.

3. Methodology:

Different modeling used have been analyzed to provide efficient and effective modeling. The modeling tools that have been analyzed include the TIMES/MARKAL, LEAP, ARIMA and MiniCam. The LEAP seems to be the best fit for this analysis as a lot of other studies at global level have been conducted using LEAP. LEAP (long range energy alternative planning) model is used for analysis for energy planning and modeling with the room of penetration for the new electricity sources in the system. Bottom up approach has been employed for the analysis and custom scenarios have been developed. The base year is set to 2016 and the end year is 2050.

Islamabad is divided into 3 divisions namely division 1, division 2 and division 3 and similarly Rawalpindi is divided into 7 sectors. The division 1 includes blue area, F6, G6, g7, Khana Dak, Nilore and Tarlai regions and division 2 includes F11, F8, G11, G9, I10 and I9 regions and similarly, division 3 includes the Bara Kahu 1 and Bara Kahu 2 regions. The Rawalpindi is divided into the 7 sectors like Sattelite town, Pindi City, Pindi Cantt, Westridge, Tariqabad and Rawat. The demand of all these regions have been analyzed both individually and combined.

3.1. Data requirements:

Data is one of the most important factors in order to observe the effective and efficient modelling and planning, a valid data has been gathered from the various resources such as visiting IESCO, Pakistan Statistical Bureau and Planning Commission along with different reports and publications. The data is then organized as per the model requirements as the data is not been provided in a ready to use form. Pakistan is a developing country and there is a huge problem with the data collection as I had to visit the IESCO, Statistical Bureau and Planning commission for the data collection [11, 13, 14]. Some other data has been salvaged from the Private power and Infrastructure Board (PPIB) in the form of surveys and reports [15].

Table 17 Data sources

S.no	Data type	Source

1	Sector-wise demand and supply data	Islamabad Electric Power Company (IESCO)
2	Plans and Policies	Planning Commission (PC), Private Power and Infrastructure Board (PPIB)
3	Demographics and reports	Energy Year Book and Pakistan Bureau and Statistics (PBS)

3.2. Key Assumptions in LEAP model:

The key assumptions of this model include the GDP growth rate, population growth rate and income growth rate as observed in the table below [13].

Table 18 Data for key assumptions in LEAP

S.No	Sectors	% growth
1	GDP	5.5 %
2	Population	2 %
3	Income	6.4 %

4. Scenario development:

4.1. Demand Side Scenario:

4.1.1. Reference Scenario (Ref):

The reference scenario which explains the business as usual situation and the Rawalpindi and Islamabad are divided or segregated into two separate regions Rawalpindi region and Islamabad region. In this scenario the residential growth rate is taken as the household growth rate in the activity level and the kwh of electricity consumption growth is taken as the final energy intensity growth rate. The table below shows the demand side data structure

Table 19 Input LEAP data

Input data	Value
No. of units	2-3%
Electricity energy intensity	3-4%
Baseload powerplants	Hydro, Oil, Natural gas

4.2. Supply Side Scenario:

The supply data scenario includes the data of all the sources that are proving electricity to the IESCO and is further being transferred to the system. IESCO is getting 90% of electricity from the hydro, 1.25% from the natural has and around 6.75% from the oil as observed in the table below.

Table 20 Supply side data for LEAP

Resources	Capacity (MW)
Hydro	2284
Diesel	31
Gas	165
Total	2480

5. Results:

5.1. Commercial Islamabad and Rawalpindi:

The figure explains the electricity demand of commercial sector of Islamabad and Rawalpindi. The demand seems to be increasing from 750 GWh in 2016 to 1300 GWh in 2050 which expresses a pretty extreme growth of around 90 %. It is important to understand that this growth in demand in only for commercial sector of Islamabad and Rawalpindi.

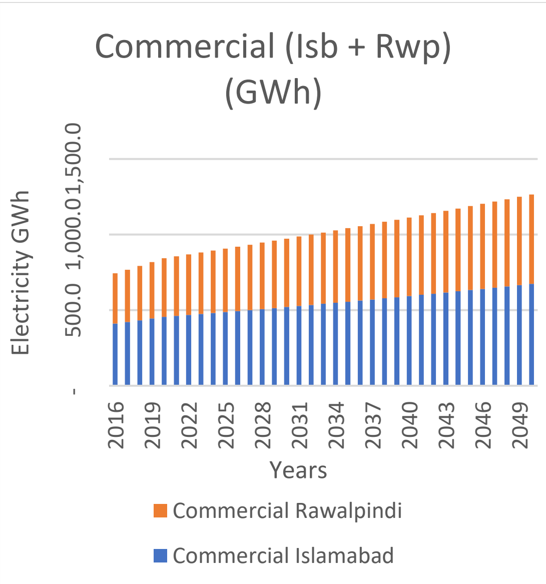

Figure 36 Islamabad and Rawalpindi Commercial demand

Now in order to see the separate demand growth we can see that the division 1 for the commercial sector of Islamabad has the growth of almost around 70 % but in talk about the maturity it is also to be taken into account as if there is enough space for new commercial activities. The F 6 has the most consumption followed by the Blue Area in division 1 with almost around 75% increased demand. Similarly, for division 2 there is an increase in the I 9 and F8 areas and for division 3 we can see a huge increase in the Bara kahu 1 due to the recent development of the region which paved way for commercial activities.

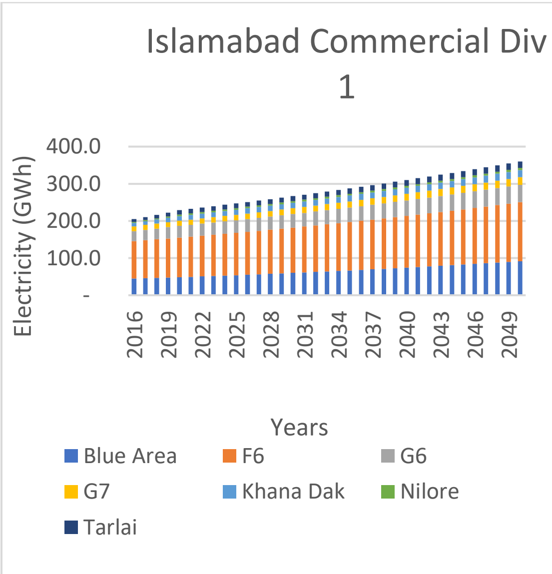

Figure 37 Commercial Demand for Islamabad division 1

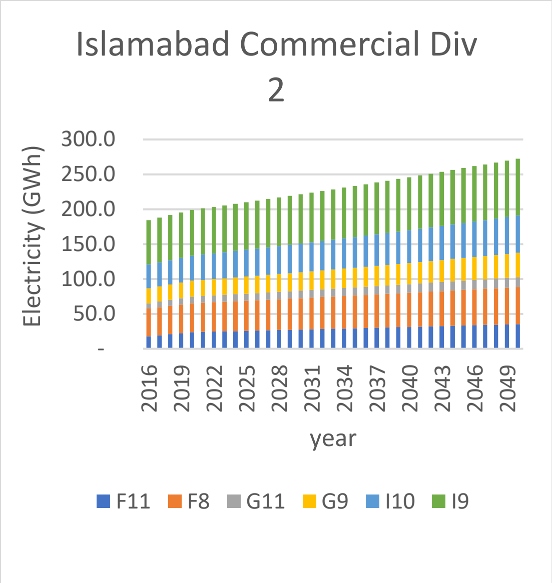

Figure 38 commercial demand for Islamabad division 2

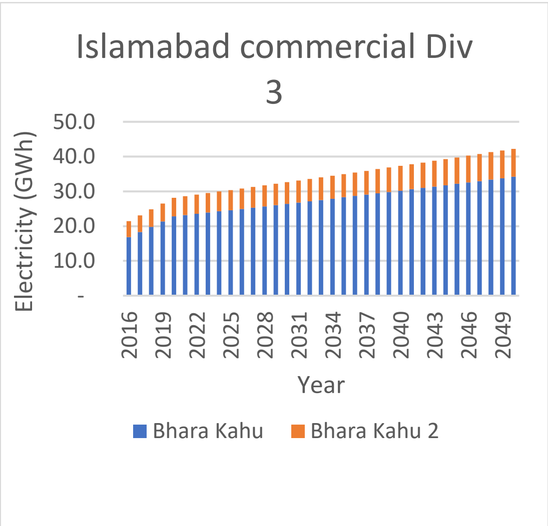

Figure 39 Commercial demand for Islamabad division 3

The commercial sector of Rawalpindi can be seen in the graph that there is also a 100% growth in the demand of this region from 2016 to 2050 and there is an overall steady increase in the electricity demand in this region

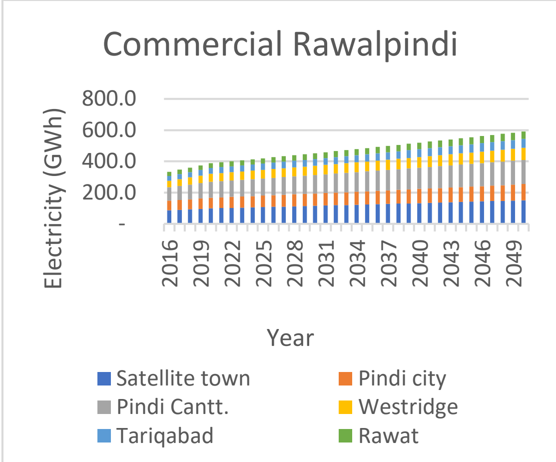

Figure 40 Commercial demand Rawalpindi division

5.2. Industrial Islamabad and Rawalpindi:

The industrial demand for both Islamabad and Rawalpindi has seem to be increasing from 300GWh in 2016 to around 520 GWh in 2050 which shows the increase of around 80%. It is imperative to note that we also have analyzed the maturity of the growth in demand. The data is presenting the mature future projection.

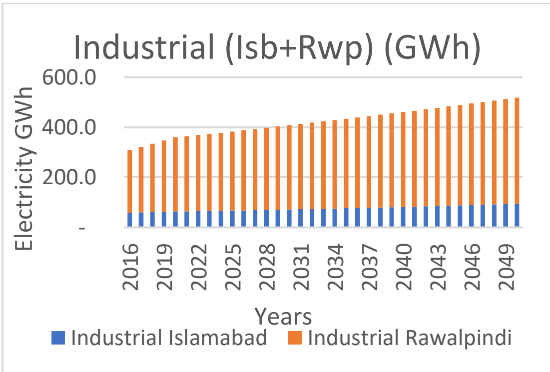

Figure 41 Islamabad and Rawalpindi Industrial demand

The division wise industrial consumption has been also analyzed. In division 1 it could be observed that the G 6 sector seems to have been growing fast in terms of industrial consumption and there is almost more than 100% increase in demand by 2050. The division 2 shows quite a steady growth in the industrial sector as this division is mostly occupied by the residential or commercial sector and there is not much room for the industrial growth but still there is a steady growth in the demand of electricity over the years. The division 3 including the areas of Bara kahu and Bara kahu 2 there is not much increase in the industrial demand as these areas are not much developed and there are not any worthwhile industrial projects.

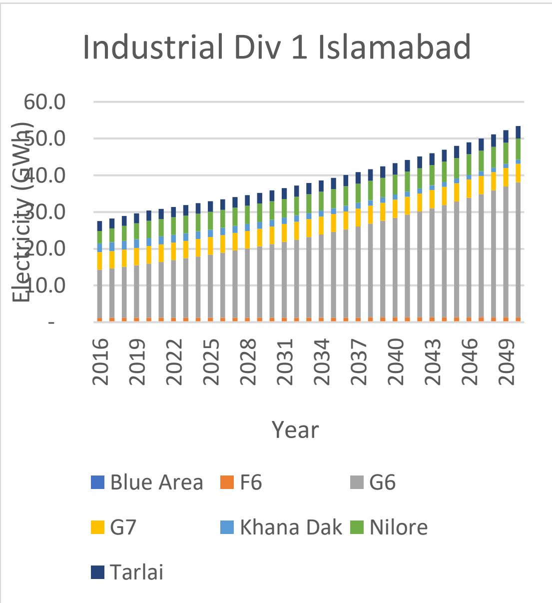

Figure 42 Industrial demand division 1 Islamabad

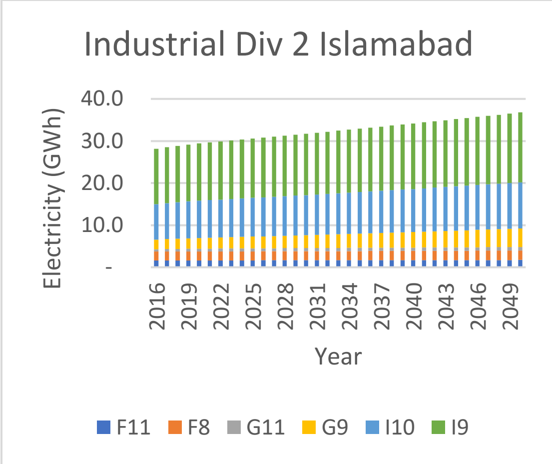

Figure 43 Industrial demand Islamabad division 2

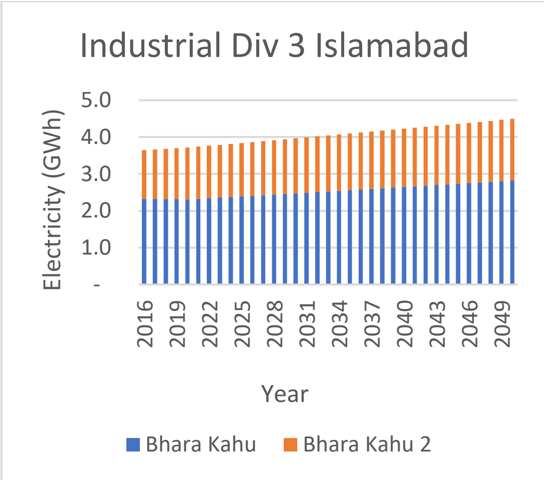

Figure 44 Industrial demand Islamabad division 3

Now moving towards the Rawalpindi industrial sector, we could find a great degree of increase with already a huge electricity demand. There is quite a huge demand in the industrial sector of this area and the demand seems to be increasing from around 250 GWh in 2016 to almost 450 GWh with the increase of around 80 %.

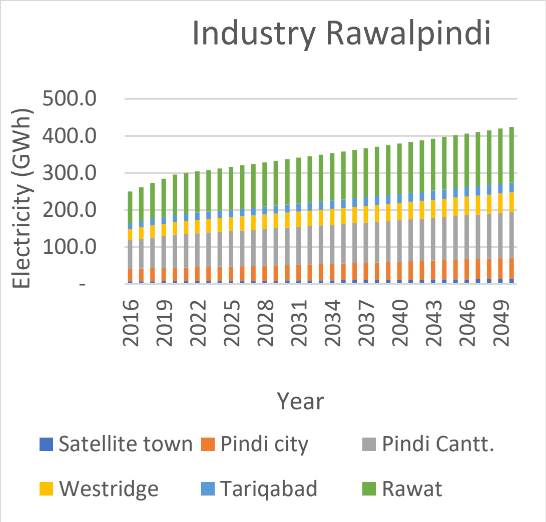

Figure 45 Industrial demand Rawalpindi

5.3. Supply side:

The business as usual scenario also known as reference (Ref) includes the supply side data for all the sectors. There is no addition of energy over the years for diesel and gas, but we can see the increase in the hydro potential over the years as the government has already initiated some projects and some projects are still to be initiated.

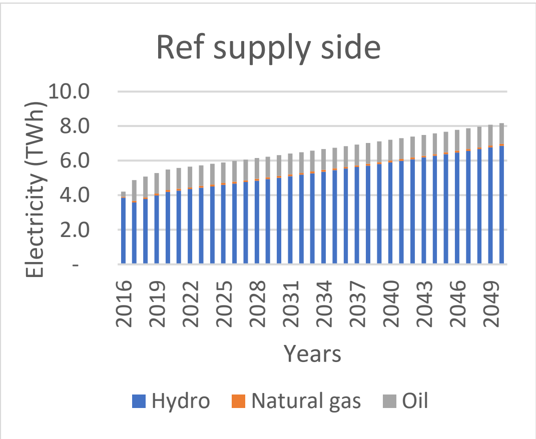

Figure 46 Overall supply

6. Conclusion:

The increase in the electricity consumption has caused a distress in the economy and sustainability of the system. There is a dire need for the national, regional and sectoral base energy policy and planning. This research analyzed the commercial and industrial sector of Islamabad and Rawalpindi and discovered how the demand will be out of the reach in coming years. Industrial and commercial sector contributes towards the economic development so proper planning and modeling is required for the sustainable future. The commercial growth has been reached to almost 80-90% by 2050 and the Industrial growth is observed to be around 80%. The industrial and commercial sector are chosen so that we could encourage these sectors to devise a plan for the future electricity demand by concentrating on the renewable energy sources.

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