Modeling and Analysis of Long-term Energy Scenarios Using LEAP Model

By

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DEDICATION

"Dedicated to my parents and teachers . . ."

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
CAGR	Compound Annual Growth Rate
CNG	Compressed Natural Gas
GHG	Greenhouse Gases
GWP	Global Warming Potential
NDVI	Normalized Difference Vegetation Index
DBSI	Dry Bare Soil Index
LAI	Leaf Area Index
NDBaI	Normalized Difference Bareness Index
NDBI	Normalized Difference Built-up Index
DBI	Dry Built-up Index
IEA	International Energy Agency
WEC	World Energy Council
NTDC	National Transmission & Dispatch Company
LPG	Liquefied Petroleum Gas
FAO	Food and Agriculture Organization
SDGs	Sustainable Development Goals
VOC	Volatile Organic Carbon
IPCC	Intergovernmental Panel on Climate Change
PCRET	Pakistan Council of Renewable Energy Technologies
LEDS	Low Emission Development Strategies
HDIP	Hydrocarbon Development Institute of Pakistan
GDP	Gross Domestic Product
TOA	Top Of Atmosphere reflectance
VIs	Vegetation Indices

ABSTRACT

The energy sector is critical for nation building, particularly in terms of economic development. The current installed capacity of electric power in Pakistan is roughly 17,000 MW, but peak demand is 22,000 MW, with an average shortage of 5,000 MW. The objective of study is to forecast energy consumption of various resources of energy, GHG emissions from these sources and finding the impact of biomass energy on current energy generation using LEAP model. According to the findings, total demand from all sources is around 98.10 million Tons of Oil Equivalent (TOE), and it is growing at an alarming rate of 2.93% each year. The most significant sources of GHG emissions are fossil fuels. With an annual increase of 2.94%, current energy use produces around 240.35 million tons of CO_2 equivalent at 100-Year Global Warming Potential (GWP). Biomass is one of the best renewable energy sources that may be used to meet energy demand while also helping to reduce pollution. The biomass of wheat, maize, sugarcane, and tobacco was estimated using spectral indices and biophysical properties of the crops, yielding a total of 1,651,043 tons, and DBSI was used to identify bare land in the area during the boom green period of each crop. Estimates of biomass energy showed that 25% of the total biomass in the study area could generate 489 MW of electricity, which could have a significant influence on energy demand generation and avoid the environmental pollution in terms of negligible GHG emissions. The use of LiDAR and drone imagery can improve classification and biomass calculation. Research into municipal and animal waste as well as advanced biomass energy production can show a path to long-term energy production.

Chapter 1

INTRODUCTION

Pakistan is geographically located between 23^0 45' and 36^0 75' north latitude and between 61^0 and 75^0 50’ east longitude and is a sub-tropical country. To the east of Pakistan is India, on the north is China, to the north-west side is Afghanistan, to the west is Iran and on the south is the Arabian Sea. There are four provinces of Pakistan named Punjab, Sindh, Khyber Pakhtunkhwa, and Baluchistan. Punjab is the province with the most population, while Baluchistan is the greatest province by area. Pakistan is a developing country and it has many natural resources in the form of water, oil, natural gas, coal, and nuclear sources for the production of different forms of energy for different uses. Indus River flows in the country for about 2500km starting from Karakorum and Himalayas to the Arabian Sea. That is why Pakistan has known the Land of Indus River. The water of the Indus River is used for different purposes such as irrigation and hydel power production. Dams made on this river generate major Hydel power of Pakistan. Other resources of energy mentioned are distributed unevenly in provinces and associated territories of Pakistan. Hydel power stations, oil, natural gas, and nuclear energy resources are under federal control while both federal and provincial governments of Pakistan maintain the coal sector. The increase in the demand of energy is growing day by day due to the high growth rate; progressive industrialization leads to severe energy crisis and makes it an issue of high concern. The deterioration of the environment caused by the uncontrolled and unsafe use of resources is highly alarming to the biotic life directly or indirectly by harming the abiotic components of the environment.

1.1 Energy as a Bottleneck for Development

Because energy is an important part of practically all human activities and developments, energy consumption is a good indicator of a country's industrial economy and people's affluence. The world's energy resources are fast decreasing due to the rising global population and people's materialistic lifestyles (Şen, 2004). Furthermore, increased energy consumption around the world has negative consequences for the earth's environment and ecosystem. The use of fossil fuels for energy generation is one of the most significant contributors to environmental degradation. Energy use and demand are on the rise, indicating that it will be one of the world's key future issues (Rafique & Rehman, 2017).

Human life is propelled by energy, which is essential for human progress. With rising human population, urbanization, and industrialization, worldwide energy consumption is rapidly expanding (Asif & Muneer, 2007). The world's energy requirements are primarily reliant on fossil fuels. Coal, oil, and gas provide over 80% of world energy consumption, among other fossil fuels. Renewable energy and nuclear power, on the other hand, currently contribute only 13.5% and 6.5% of the world's total energy demands, respectively (International Energy Agency, 2007).

The provision of sufficient, secure, and inexpensive energy is essential for human development to continue. The human demand for energy has risen steadily throughout history, paralleling the expansion of civilizations. Global energy demand is expected to increase dramatically in the future years. The global daily oil consumption is currently 85 million barrels, with conservative forecasts predicting that this figure will climb to 113 million barrels by 2030. Because fossil fuel supplies are already depleting, present energy resources will not meet future energy demands (Asif, 2009).

The global use of energy has increased dramatically in recent decades, from 8,588.9 Million Tons of Oil Equivalent (MTOE) in 1995 to 13,147.3 Million Tons of Oil Equivalent (MTOE) in 2015 (Dong et al., 2020). Every policy must include energy performance as one of the fundamental pillars to ensure inclusive and sustainable economic growth worldwide. Cost-effective strategies to improve energy supply security, minimize the climatic footprint of energy networks, and improve the International Energy Agency's (IEA) welfare and competitiveness are still in place (Zerta et al., 2008). Total primary energy consumption (about 80%) came from fossil fuels in the recent era. Several government organizations, including the World Energy Council (WEC), the Organization of Petroleum Exchange Countries, and the World Mega-Oil Organization, have looked at a considerable number of prospective global energy forecasting studies (Ahmad & Zhang, 2020).

1.2 Energy mix of Pakistan

Pakistan is endowed with nearly all types of energy resources, which, if well utilized, can boost the country's economy. Pakistan's power sector is under the direct or indirect authority of the government or several commercial institutions. Pakistan had a 60MW power generation capacity when it gained independence in 1947. In the early decades, the power sector had made significant advances. After 1970, the power infrastructure improved, and it continued to do so until the 1990s. Pakistan has a large energy generation potential due to a variety of indigenous energy resources. In terms of coal output, Pakistan is the sixth most prosperous country in the world.

Furthermore, Pakistan's nuclear power initiatives, which began in 1954 and were launched by the Pakistani government, can produce electricity (Rauf et al., 2015).

Pakistan sees a dramatic increase in energy deficit and demand due to rising population and industrialization. In terms of primary and secondary energy resources, Pakistan's primary and secondary energy resources are fossil fuels (Mirza et al., 2007). During 2011-2012, the country's total primary energy supply was 64.727 Million Tons of Oil Equivalent (MTOE). Nearly 87% of the energy is supplied directly or indirectly by fossil fuels such as oil, coal, gas, and LPG, while just around 1% of the total energy is produced by renewable energy resources (M. Farooq & Shakoor, 2013). Natural gas accounted for 49.5% of Pakistan's energy mix in 2011-2012, followed by oil (30.8%), hydroelectricity (12.5%), coal (6.6%), nuclear electricity (1.9%), LPG (0.5%), and imported electricity (0.1%) (Ghafoor et al., 2016).

1.3 Energy Crisis in Pakistan

As of June 30, 2015, the gap between energy demand and supply in Pakistan was 5201MW, resulting in a daily blackout of 14-18 hours, as has been the case for the past few years (*State of Industry Report*, 2015). In 2008-2009, the government spent $9 billion to meet the nation's energy demands, which strains the economy. Despite a total installed capacity of 24,823MW, with thermal power plants accounting for 67.74% of the energy mix, the demand of 21,701MW was not satisfied, resulting in a 5201MW deficit. According to the National Transmission and Dispatch Company (NTDC), it is expected to last until 2018 (Kamran, 2018).

Pakistan's power industry is mainly under the jurisdiction of either government ministries or commercial organizations, either directly or indirectly. The energy infrastructure of Pakistan is underdeveloped, inadequate, and poorly managed. Domestic, industrial, transportation, agricultural, commercial, and other government use sectors are the major energy sectors in Pakistan. Power availability is around 17,000MW, peak demand is 22,000MW, and the average shortage is roughly 5000MW. Electricity demand is increasing at a 10% annual rate, while supply increases at a 7% yearly rate. In urban and rural locations, outages last roughly 7-10 hours and 15-20 hours per day, respectively. This indicates that by 2030, the power demand will exceed 45,000MW (Rauf et al., 2015).

1.4 Environmental Pollution caused due to Energy Production

Due to an imbalance in the carbon cycle, severe climatic changes are now considered a major problem in the modern era. There are two primary solutions to balance the world's carbon cycle: reducing carbon emissions and increasing carbon absorption capacity, or both. Infrastructure, natural resources, agricultural output, and human life have all been lost due to environmental degradation (Harris & Feriz, 2011). The United Nations Framework Convention on Climate Change (UNFCCC) was established in 1992 to regulate greenhouse gas emissions, and under the Kyoto Protocol accord (1997), industrialized countries were obligated to do so. Between 2010 and 2040, energy consumption will increase by 56%. Carbon dioxide (CO_2) emissions, the primary component of overall GHG emissions, have increased due to increased energy use. The energy sector is responsible for 61.4% of GHG emissions (Khan et al., 2018).

According to the International Energy Agency (IEA), global primary energy demand is predicted to grow at 1.8% per year between 2005 and 2030. The rise in global energy demand will be fueled mainly by developing nations, accounting for

74% of the increase. Furthermore, only two countries, China and India will account for 45% of the world increased energy demand. Primary demand in China and India is predicted to expand at average annual rates of 3.2% and 3.6%, respectively, from 2005 to 2030. Understanding the factors that influence energy demand is crucial for predicting how the demand for energy in rising countries will change in the future (Sadorsky, 2010).

World energy demand in various scenarios, including the current state-of-the-art, allows the disastrous impact of global warming on a variety of conditions where governments and people work together to achieve the Paris Agreement objective of well below 2^0 C. In September 2015, 189 countries, including both wealthy and developing countries, signed the Sustainable Development Goals (SDGs), officially known as the 2030 Agenda for Global Development of SDGs and Corporation (Omer & Noguchi, 2020). As a result, air pollution is receiving much attention, and it is directly linked to two of the Sustainable Development Goals: SDG 11.6 (mitigation of air pollution effects on people in large cities) and SDG 3.9. (significant reduction in health effects due to hazardous element) (Ahmad & Zhang, 2020).

Short-term climate changes continue to occur in the environment, but GHG in the atmosphere causes long-term alterations. 65% of CO_2 is released during fossil fuel burning and industrial operations, whereas 11% is released through forestry and land use patterns. Energy (25%), agriculture (24%), industry (21%), transportation (14%), energy-related activities (10%), and buildings (all contributing to GHG emissions) (10%). Annual energy usage has topped 14 GTOE, with carbon emissions exceeding 10Gt. Due to arctic sea ice disappearing at a pace of 2.7% per decade, the global average temperature has climbed by 0.74^0 C, and sea level has risen by 1.8

millimeters per year since 1961 (Brunner & Baum, 2014). The IPCC forecasts temperature rises of 1.5-5.8^0 C forecasts temperature rises of 1.5-5.8^0 C forecasts temperature rises of 1.5-5.8^0 C for the twenty-first century. Pakistan's GHG emissions include 158.10 Mt of CO_2 (54%), 111.60 Mt of CH4 (36%), 27.90 Mt of N2O (9%), and 0.93% of volatile organic carbon (VOC) (0.3%). Pakistan's cumulative CO_2 emissions are expected to reach 250 Mt by 2020, potentially rising to 650 Mt if fossil fuel subsidies are maintained. According to a 2008 national greenhouse gas inventory, the energy and transportation sectors contribute the most, accounting for over half of Pakistan's total GHG emissions, while the agricultural sector contributes 39%. CO_2 emissions from the steel industry are 1.27 kg/kg of steel produced (Abas et al., 2017).

1.5 Renewable Energy for Sustainable Development

Sustainable development is defined as keeping the number of resources consumed by society for today's requirements at a level that does not deprive future generations of those resources. Sustainable development, according to this definition, has three dimensions: economic, social, and environmental. As a result, to achieve sustainable development, it has become imperative to meet the ever-increasing energy demand (Ozturk & Acaravci, 2011). In this regard, meeting rising energy demands using renewable energy sources such as geothermal, solar, wind, biomass, and biofuels will assist in limiting pollution of the sources to a minimum, allowing for long-term development. According to estimates, renewable energy has a positive impact on sustainable development in both developed and developing countries. The United Nations (UN) is responsible for the most important pioneering study in this sector. The United Nations has highlighted the activities countries should take by 2030 to achieve sustainable development by defining 17 Sustainable Development Goals (SDGs) (Güney, 2019).

The analysis of current conditions and forecasting in the energy sector are critical components in formulating long-term strategies for the economy's long-term development. The interaction between the economy and its key sectors, energy and the environment is crucial (Eder & Nemov, 2017). In order to reduce greenhouse gas emissions, European countries set goals for energy efficiency and extensive use of renewable energy resources, which they have met and have made them world leaders in their use. By 2020, the target is for renewable energy to account for at least 20% of total energy consumption, with that figure rising to 27% by 2030 (Eder et al., 2018).

Biomass energy is viewed as a viable alternative for attaining sustainable development and plays an essential part in developing countries among renewable energy resources because of its advantages, economic and social benefits. It will aid in raising awareness of the economic, environmental, and social components of sustainable development, as well as ensuring the continuity of progress in society's common ideals, such as a high standard of living (Güney & Kantar, 2020).

1.6 Biomass as a Source of Renewable Energy

Pakistan is the world's sixth most populous country, accounting for 2.56% of the global population. However, it ranks 37th in terms of energy consumption, accounting for 0.37% of global consumption. The energy availability per capita is only 43W, which is $1/7^{th}$ of the global average. Apart from non-renewable energy sources, there are four main sources of renewable energy: hydel, solar, wind, and biomass, all of which have significant potential to alleviate the country's energy shortfall. With respective percentages of 35% and 65%, hydel and thermal power plants account for 95% of total electricity output in Pakistan. According to a recent study based on thirty years of data (1971-2000) to estimate global solar radiation, more than 70% of the country's 0.8 million-km^2 area receives radiation energy of 5.0-5.5 kW/m^2/day (Adnan et al., 2012). Pakistan has about 57 million animals capable of producing over 21 million-m^3 biogas and 36 million tons of bio-fertilizer every day. PCRET has erected over 4000 biogas plants in Pakistan to meet family domestic fuel needs and produce bio-fertilizers. These facilities have an annual biogas generation capacity of more than 2.5 million-m^3 and produce 4 million kg of fertilizer per year. Biogas facilities are one of Pakistan's fastest-growing renewable energy technologies (Farooqui, 2014).

Electricity demand grew at an annual rate of 8% on average between 2005 and 2010, and this trend is predicted to continue through 2035. In 2050, if current growth rates continue, the total demand will be 474GW. According to the power generating plan to 2030, the electricity supply would grow at an average annual rate of 11% until 2030, with thermal-based electricity generation accounting for 65% of the increase in installed generation capacity (Economic Survey of Pakistan, 2010). In such conditions, boosting fossil-based generation will not only increase emissions but also it may also raise energy prices due to rising fossil-fuel prices. Until 2010, renewable energy accounted for less than 1% of Pakistan's power generation. As a result, Pakistan must make full use of domestically accessible alternative energy sources for electricity generation (M. K. Farooq & Kumar, 2013).

1.7 The Low Emissions Analysis Platform (LEAP)

The Low Emissions Analysis Platform (LEAP) was developed at the Stockholm Environment Institute and is a widely used software tool for energy policy analysis and climate change mitigation evaluation. Thousands of organizations have embraced LEAP in over 190 countries around the world. It has been applied at all scales, from towns and states to national, regional, and worldwide applications. LEAP is rapidly becoming the de facto standard for countries conducting integrated resource planning, greenhouse gas (GHG) mitigation assessments, and Low Emission Development Strategies (LEDS), particularly in developing countries, and many countries have chosen to use LEAP as part of their commitment to reporting to the United Nations Framework Convention on Climate Change (UNFCCC) (Heaps, 2021).

Possible countries participating in the Asian Energy Security Project use the LEAP modeling system, a comprehensive energy-environment analysis tool, to investigate the effects of various future energy policies (Huang et al., 2011).

Cities consume over 75% of the world's energy and account for more than 80% of global greenhouse gas (GHG) emissions; as a result, they attract programs aiming at energy saving and emissions reduction (*World Energy Outlook*, 2008). The LEAP model's primary purpose is to examine future trends in energy demand and carbon emissions under various scenarios and extrapolate energy consumption and carbon emission data to anticipate values for future years. The findings serve as a guide for future energy planning and policymaking and highlight potential initiatives to establish a sustainable city. It also offers recommendations for energy conservation, carbon reduction, and low-carbon growth in cities (Feng & Zhang, 2012).

The requirement for increased generation capacity is related to electricity consumption, power outages, infrastructure, and energy economics; appropriate electricity supplies are necessary for a country's economic progress. Another concern is the scarcity of potential funding (Ghanadan & Koomey, 2005). The LEAP software, an accounting scenario-based energy modeling platform, can be used to evaluate these various situations. It is possible to examine emissions using the LEAP model concerning changes in power generation structure or the diffusion of certain generation technologies (Perwez et al., 2015).

The LEAP system may be used to create numerous scenarios of expected energy consumption and environmental impact based on how energy is consumed, transformed, and created in a specific region or economy under various parameter values such as population growth, gross domestic product, etc. and income. The LEAP model offers a flexible data structure that is easy to use and contains a wealth of technical and end-user information. It has been widely used to forecast energy supply and demand, predict the environmental impact of energy policy and anticipate future issues (Emodi et al., 2017).

LEAP's modeling approaches include both the demand and supply sides of the energy equation. LEAP provides a set of techniques accounting and simulation to estimate electricity generation and plan for its expansion. The LEAP Scenario Manager allows you to create a base/reference/Business as Usual scenario. The proposed alternative strategies can be evaluated by comparing the acquired values to those of reference methods (Meryem et al., 2013).

1.8 Objectives

The main objectives of the study were:

1. To estimate and predict energy supply and demand regarding the current generation and consumption scenario situation, using the LEAP model in Khyber Pakhtunkhwa, Pakistan.
2. To calculate and forecast the amount of greenhouse gases (GHG) generated by the currently used energy resources and situation according to IPCC Tier 1 default emission factors by LEAP model.

3. To develop an alternate way of producing energy through biomass to minimize either the demand or replace the energy resources causing environmental pollution and compare efficiency by incorporating it in the LEAP model scenario.

1.9 Significance of Research

Overpopulation, overconsumption, untapped renewable energy possibilities, and other factors contribute to the current global energy dilemma. The need for energy is increasing due to rising industrialization and domestic necessities, while non-renewable resources are rapidly depleting. Global warming is accelerating at an alarming rate because of greenhouse gas (GHG) emissions caused by using these resources. To meet the essential energy demand and combat climate change, we must reduce our reliance on non-renewable resources and shift to renewable energy supplies. These days, Biomass energy technology is one of the most environmentally friendly ways to generate electricity. Woody biomass and animal manure are two of the most common sources of biomass energy. Biomass is one of the essential energy sources for now and the future, given its technical and economic feasibility. Biomass resources help to solve energy reliance and national energy security issues by reducing the amount of energy needed from oil-exporting countries with political power issues. Choosing biomass as an alternative source also helps countries minimize their trade deficits.

By strengthening the agricultural economy, biomass employs in rural regions and reduces poverty, and it is effective in addressing global issues such as global warming, climate change, air pollution, and acid rain. This research attempts to encourage renewable energy resources for energy production while also reducing GHG emissions. The study aimed to examine energy consumption such as electricity, crude oil, natural gas, coal, and LPG in various sectors such as domestic, commercial, industry, agriculture, and transportation, as well as predict GHG emissions due to non-renewable energy resource depletion based on Intergovernmental Panel on Climate Change (IPCC) estimates for various sources. The research will aid in forecasting energy supply and demand as well as estimating Greenhouse Gases (GHGs) in the respective sector corresponding to the type of fuel used for energy generation using the Cumulative Annual Growth Rate (CAGR), as well as the increase in Greenhouse Gases (GHGs) emissions in the various sectors mentioned above. Furthermore, the study's findings will aid in determining the amount of energy lost in various types of energy, which will aid in identifying defects in the infrastructure used to transport energy and interpreting the life span of exhausting fossil resources. Most significantly, it will alert society to global warming and the alarming rate at which the environment is being increasingly polluted, affecting the habitat of living beings and leading to an increase in endangered species as well as the spread of numerous fatal diseases. The goal of the research is to create alternative energy production scenarios that will encourage people to use renewable energy resources because of the positive influence on energy supply and demand and the environmentally friendly approach to energy production.

1.10 Literature Review

Energy is a basic requirement for existence and a critical aspect of a country's economic success. Despite having abundant natural energy resources, Pakistan relies on foreign supplies and is currently experiencing acute energy shortages. Pakistan has become an energy-deficient country due to the ever-widening gap between supply and demand, with the majority of the population having no or restricted access to electricity (Ghanadan & Koomey, 2005). Pakistan has been experiencing acute energy shortages for the past decade due to its growing population and heavy reliance on fossil fuel imports. Power outages lasted 14-18 hours in rural areas, whereas, in urban areas, outages lasted 8-10 hours. Currently, the government faces significant difficulty in ensuring the country's future energy supplies. The crisis has had a significant impact on the country's residential, industrial, and commercial sectors. During the recent decade, the electricity gap ranged between 4000 and 6000MW (Ghafoor et al., 2016). The majority of the northern areas are still without power. The energy supply and demand gap is expanding and will continue to do so in the future. Because the country's fossil fuel supplies are limited, they must import to make up the difference (Rafique & Rehman, 2017). Energy availability has a substantial correlation with a country's economic and social stability. The per capita energy consumption is a metric for gauging a society's prosperity. Pakistan is an energy-deficient country, according to an evaluation of the energy scenario. In 2004-2005, the average per capita power use was 425kWh. During the same period, the global average per capita electricity usage was about 2516kWh, over six times that of Pakistan. (Asif, 2009). Because of the dominance of expensive imported oil in Pakistan's energy mix over the last two decades, the mismatch between energy demand and supply has grown. In order to meet the country's energy demands, the government paid a large sum in 2008-2009 to import crude oil, putting a strain on the national economy. The long-term economic viability is dependent on the energy sector's long-term viability (Kamran, 2018). Pakistan's energy issue is a result of bad planning and mismanagement in the energy sector. A lack of electricity, poor-quality instruments, an inefficient energy mix do not solely cause the problem, and increasing transmission and distribution losses are all contributing factors. Pakistan relies largely on imported fossil fuels to generate electricity. The national exchequer has a significant financial burden due to the importation of such fuels (Shahid et al., 2020). It is now common knowledge that energy is one of the most efficient and quick ways for a country's socioeconomic operations to improve. In Pakistan's 60-year history, the country is currently experiencing the biggest energy crisis, which has pushed the country's socio-economic growth below crucial levels of sustainability and people's tolerance. Since the previous few years, every aspect of living and industrial activity has suffered as a result of daily power outages (Nayyar et al., 2014). Weather conditions such as air temperatures, precipitation, atmospheric pressures, humidity levels, wind flows, sunshine intensities, and cloud cover are all examples of climate. Climate change is defined as any change in the weather relative to previous short or long-term measurements. Oceans absorb some carbon dioxide (CO_2) produced by respiration and fossil fuel combustion, while the rest accumulates in the atmosphere. 7.2 billion Individuals emit 2.63Gt of CO_2 per year at a rate of 0.058gm every exhale (12 exhales per minute). Annual GHG emissions have surpassed 53Gt CO_2-equivalent, with CO_2 accounting for around 40Gt. (Abas et al., 2015). Despite significant attempts to minimize CO_2 emissions, recent modeling simulations reveal that by 2100, CO_2 emissions are anticipated to climb to 51.88Gt, which would be 52.9% higher than 2010 levels. The average GHG concentration is 430 parts per million, with CO_2 accounting for 402 parts per million. From 1880 to 2015, the average temperature rise was 10^0 C, which is halfway to the Intergovernmental Panel on Climate Change (IPCC) objective of 20^0 C (Abas et al., 2017). The agriculture sector accounted for 14-30% of global GHG emissions because of excessive usage of fossil fuels. However, the Food and Agriculture Organization (FAO) acknowledged that the agricultural sector could reduce GHG emissions or remove 80-88% of CO_2. Coal-fired power plants accounted for 41% of global electricity generation. In Pakistan, coal accounted for 5.4% of total primary energy use and less than 1% of the power sector in 2014 (Khan et al., 2018). Energy demand modeling is also critical for better understanding how to manage global greenhouse gas (GHG) emissions, as energy-related GHG emissions account for most GHG emissions. Historically, rich countries have emitted most global GHG emissions; however, as emerging countries' economies grow, they are predicted to emit increasing GHG emissions (Sadorsky, 2010). When fossil fuels are burned, a certain amount of residue is left behind in the form of solids and gases. Because this residue, which is created by fossil fuels, cannot be reused in any way, it pollutes the environment. According to the seventh SDG, everyone should have access to affordable, dependable, modern, and sustainable energy. The relevance of renewable energy for long-term growth has been emphasized in this regard. However, there is a lack in the literature discussing the effects on sustainable development, in contrast to the relationship between renewable energy and carbon emissions (Güney, 2019). Economically, environmentally, and socially, sustainable development has three components. Economically, it refers to the continuous production of commodities and services and the avoidance of sectoral imbalances that could affect agricultural and industrial production. Keeping the resource base constant for sustainability indicates that renewable resource systems should not be exploited. Nonrenewable resources, on the other hand, should be consumed in proportion to the quantity of money invested. Socially, sustainability implies that social services such as equality, health, education, and political responsibility should be provided (Güney & Kantar, 2020). The establishment of a relationship between renewable energy development, fossil energy prices, hydrocarbon production to the consumption ratio, corruption index, and country technological development factors using panel data revealed a significant influence on renewable energy consumption, which was received. A 1% change in hydrocarbon prices results in a 1.05% change in renewable energy source consumption. Major technological restructuring will be necessary to increase renewable energy's competitiveness in the face of inexpensive fossil energy resources (Eder et al., 2018). Renewable energy for power generation is increasing in popularity around the world, and these resources can meet Pakistan's current and future energy needs. Solar energy's technical potential is expected to be 149GW in 2010 and 169GW in 2050. There is enough space for 13GW of wind energy producing capacity to be installed in a sustainable area. In 2010, biomass energy sources had a potential capacity of 5GW, which may increase to 15GW by 2050. Under current conditions, small hydro installed capacity can exceed 3GW installed capacity (M. K. Farooq & Kumar, 2013). Long-term forecasting of power demand and supply has become increasingly important in fundamental research aimed at finding long-term solutions to electricity problems. Based on economics, technically, and implied environmental concerns, the LEAP model was used to examine Pakistan's supply policy selections and demand assumptions for the future power generation system. The outcomes of various scenarios were compared in terms of predicted power demand and supply, net present cost analysis, and reductions in GHG emissions, as well as sensitivity analysis to investigate the impact of changing parameters on total cost (Perwez et al., 2015). Four scenarios were used to examine the influence of various energy policies on the Nigerian energy sector. When aggressive energy policies and initiatives are taken into account, REF scenario energy demand is predicted to reach 3,075PJ by 2040, with a corresponding increase in GHG emissions of 201.2Mt CO_2. A cost-benefit analysis and a study of the energy system were also carried out (Emodi et al., 2017). The LEAP model was used to track the production and consumption of non-woody waste biomass (from crops and animals) in Pakistan, as well as its potential as a renewable energy source in the future. A reference scenario was established based on the current biomass situation, followed by two alternative scenarios to anticipate future biomass demand and availability as a renewable energy source. The results of the model show that the activity level of biomass will change with different scenarios for both animal and crop waste. It increased from 168.9 million tons in 2010 to 548.5 million tons in 2030 for animals, and from 85.5 trillion tons in 2010 to 152.2 trillion tons in 2030 for crops (Meryem et al., 2013). Remote sensing can provide synoptic views of an area of interest with high temporal resolution that would be impossible to obtain using traditional data collection methods. Using satellite imageries from various remote sensing systems, remote sensing researchers have spent much time and effort creating methods and models for estimating vegetation biophysical parameters as canopy closure, leaf area index (LAI), biomass, and stand age (Wei, 2010). Satellite platforms provide a cost-effective method of collecting data over wide areas. The normalized difference vegetation index (NDVI) is the most extensively used known vegetation index that can be derived from remote sensing data, and it has been proved a sufficiently reliable indicator for monitoring intra- and inter-annual vegetation greenness fluctuation. Technical and economic constraints, on the other hand, frequently limit the capacity of remote sensing sensors to capture data with high spatial and temporal resolution at the same time (B. Zhang et al., 2016). Except in green light, leaves' physiological and structural properties determine their low visible light reflectance. The LAI, which is derived from optical remotely sensed data, is a critical measure for estimating vegetation's aboveground biomass. Fine resolution spatial and spectral (hyperspectral) remotely sensed data are being used to obtain LAI and other biochemical components such as chlorophyll in the leaves of plants due to their recent availability (Zheng & Moskal, 2009). The spectral properties of dry and semi-arid regions differ from those of other climate zones. As a result, suitable remotely sensed indicators of land use and land cover types for arid and semi-arid areas must be defined, as indices developed for other climatic zones may not produce believable results in arid and semi-arid regions (He, 2010). Normalized difference built-up index (NDBI) and normalized difference bareness index (NDBaI), for example, cannot tell the difference between built-up areas and bare and dry soil. The dry built-up index (DBI) and the dry bare-soil index (DBSI), two newly designed indices, have been employed, with overall classification accuracy of 93% (k = 0.86) and 92% (k = 0.84) for DBI and DBSI, respectively (Rasul et al., 2018).

1.11 Vegetation Indices for Biomass Estimation and Bare land

The spectral qualities of green plants are highlighted by vegetation indices (VIs), which can be separated from other traits. These spectral bands have been mathematically combined. These can be determined using a mixture of the red spectral band (chlorophyll absorbent) and the near-infrared band (non-absorbent), with some indices additionally including the short-wave infrared band. Computation can be done by forming a linear combination of bands, rationing, differencing, rationing differences, and sums. (X. Zhang & Ni-meister, 2014). For many years, VIs have been employed in agriculture and forestry.

In the agricultural industry, VIs such as NDVI are utilized to study crop health. The higher the NDVI number, the healthier the vegetation, and vice versa (Eq. 1). VIs are also utilized to calculate agricultural biomass. (Wiegand et al., 1991). The Normalized Difference Built-up Index (NDBI) is a novel method for automatically mapping built-up regions that were introduced in 2003. Despite discriminating between built-up and vegetated or green and wet land cover, the NDBI index was unable to distinguish between built-up and other land cover types such as bare and dry soil due to overlapping spectral reflectance (Eq. 2). NDBI results generate a high value for bare soil, whereas NDBaI results produce a high value for built-up, based on many tests utilizing NDBI and NDBaI. In a dry climate, the proposed bareness area equation is the inverse of the Modified Normalized Difference Water Index (MNDWI) (Rasul et al., 2018). The Leaf Area Index (LAI) is a dimensional less variable representing the leaf area to ground surface area per unit. Long-term LAI monitoring can help researchers better understand the effects of dynamic changes in productivity and climate on plant ecosystems.

Furthermore, LAI can be used as a stress indicator in plants. Measurements of LAI collected from remotely sensed data that are spatially explicit are an essential component for modeling and simulation of ecological variables and processes (Zheng & Moskal, 2009). It measures the amount of foliage that contributes to biomass and affects evapotranspiration and photosynthesis (Eq. 3). In order to simulate crop biomass and yield under a variety of agro-climatic variables and spatial scales, precise spatial LAI must be assimilated (Chaurasia et al., 2011).

1.12 Problem Statement

Energy has long been a roadblock in a country's progress. The leading causes of energy growth are energy policies that change over time and the rate at which population and economic activity develop. The global GDP is expected to expand at a 3.4% annual rate, while the population is expected to increase from 7.4 billion in 2016 to 9.1 billion in 2040. In terms of main and secondary energy resources, Pakistan's energy sector is significantly reliant on fossil fuels, according to the current state of energy in Pakistan. 87% of total energy is generated directly or indirectly using fossil fuels, which significantly influences the environment in terms of greenhouse gas (GHG) emissions. These gases harm the ecology, making it unfit for living things. According to statistics, demand has increased, but supply has failed to keep up with the rising need. As a result, it is necessary to assess the current energy supply and demand picture to understand the exponential rise in energy demand in various industries. Because fossil fuels are utilized to provide the majority of energy, it is critical to assess the pollution they cause in order to inform society how vulnerable the atmosphere is to these hazardous chemicals. Furthermore, to underline the need for sustainable development by transitioning to renewable energy sources and demonstrating how it positively influences the present energy nexus.

Chapter 2

MATERIALS AND METHODS

2.1 Study Area

Peshawar, Charsadda, Mardan, Swabi, and Nowshera have been chosen as the study region, encompassing most of the Peshawar Valley (Fig. 1). The location of the study area is between 34^{0} 1' 33" to 34^{0} 12' 22" N and 71^{0} 33' 36" to 72^{0} 38' 12" E. The elevation of Peshawar, Charsadda, Mardan, Swabi, and Nowshera is 317m, 302m, 315m, 341m, and 294m respectively. The most fertile soil in Khyber Pakhtunkhwa may be found in these districts. The Valley covers an area of 7,176 square kilometers. The major cultivated crops in the study area are Barley, wheat, sugarcane, and tobacco, but vegetables are planted. The region is thought to be one of the cultivable and productive lands in Khyber Pakhtunkhwa. Peshawar, Charsadda, and Mardan are located on the Kabul River flowing through Nowshera, whereas Swabi is located on the Indus River, which flows on the eastern bank of Nowshera.

2.2 Datasets Description

Electricity

The National Electric Power Regulatory Authority (NEPRA) provided information on energy supply, demand, and consumption in many sectors, including domestic, commercial, industrial, agricultural, street lighting, bulk supplies, and government use. The Energy & Power Department of the Government of Khyber Pakhtunkhwa also provided information on the area's installed energy capacity, which exclusively includes hydel power generation. In 2017-2018, Khyber Pakhtunkhwa generated 4,208 MW out of 7,129 MW, accounting for around 60% of Pakistan's total hydel power. Tarbela, Warsak, Duber Khwar, Allai Khwar, and other major dams contribute to electricity generation. Many more dams are currently being built for electricity generating and irrigation purposes.

Crude Oil

Data on fuel oil consumption in various sectors such as domestic, industrial (including cement manufacturing), agriculture, transportation, power, and government organizations is obtained from the Hydrocarbon Development Institute Pakistan (HDIP), Oil and Gas Development Company Limited (OGDCL), and KPOGCL. According to data from HDIP, OGDCL, and KPOGCL, Khyber Pakhtunkhwa generates 16,344,032 of Pakistan's total crude oil output of 32,557,052 barrels per year accounting for about half of the country's total crude oil production in 2017-2018. Nashpa, Makori East, Maramzai, and Mardan Khel are the main fields that contribute to the output. To meet the daily energy needs, surveys are being carried out to discover crude oil deposits.

Natural Gas

Sui Northern Gas Company Limited (SNGPL), Oil and Gas Development Corporation Limited (OGDCL), and Hydro Carbon Development Institute Pakistan (HDIP) provide information on natural gas supply, demand, and consumption in various sectors such as domestic, commercial, industrial (general industries, cement, fertilizer as feedstock and as fuel), power, and transportation. There are two types of natural gas production: associated and non-related gas production. Khyber Pakhtunkhwa's non-associated natural gas production is 150,004 of 1,443,907 million CFt, accounting for around 11% of Pakistan's total non-associated natural gas production. In 2017-2018, Khyber Pakhtunkhwa produced 1,174 million CFt of related natural gas out of 15,030 million CFt, accounting for nearly 8% of Pakistan's total associated natural gas output. Positive initiatives are being done to boost natural gas output, as energy is the backbone of a country's development and wealth.

Coal

According to the Labor Department of the Government of Khyber Pakhtunkhwa, Khyber Pakhtunkhwa produces 459,904 tons of coal out of 4,297,195 tons, accounting for around 8.7% of Pakistan's total coal production. In Khyber Pakhtunkhwa, coal is mostly used in brick kilns and cement plants. In other parts of the country, it is also employed in thermal power plants. Because Khyber Pakhtunkhwa has no thermal power facilities, it has no contribution to this sector's usage. Environmental pollution is a crucial concern associated with coal usage; severe measures are being implemented to reduce greenhouse gas emissions caused by coal combustion to protect the environment.

LPG

According to data from the Oil and Gas Development Corporation Limited (OGDCL) and the Hydrocarbon Development Institute Pakistan (HDIP), LPG was produced in 181,340 tons out of 1,128,633 tons for 16% of total LPG output from gas plants. Furthermore, 344,645 tons of the 653,655 tons produced contributed to nearly 53% of total LPG output from oil fields. LPG is mainly used in the home, business, and industry. Because it is linked to oil and gas fields, new finds in these fields will increase LPG production, helping to supply the need for energy.

Remote Sensing Data

The sentinel-2 level 1C satellite image, consisting of a 100 * 100 km^2 tile (ortho rectified imagery with UTM/WGS84 projection system), is downloaded for four different crops, including Maize, Wheat, Sugarcane, and Tobacco, of different dates showing their maturity periods. Cloud cover was less than 10% in all images, snow cover was minimal, and vegetation was primarily visible. The image was already pre-processed into Top of Atmosphere reflectance (TOA). As a result, compared to other satellite images, it required very little pre-processing. The image was chosen for the investigation because it has a higher spatial resolution than other open-source satellite products. Its Red, Blue, Green and NIR bands have a 10-m resolution, making it ideal for vegetation investigations. It also has three red-edge spectral bands that can be used to monitor vegetation.

2.3 The Low Emissions Analysis Platform (LEAP)

LEAP (Low Emissions Analysis Platform) is a robust and extensible software system developed at the Stockholm Environment Institute for integrated energy policy analysis, planning, and climate change mitigation evaluation. Thousands of organizations in over 190 countries around the world have embraced LEAP. It has been applied at all scales, from towns and states to national, regional, and worldwide applications. LEAP is quickly becoming the de facto standard for countries conducting integrated resource planning, greenhouse gas (GHG) mitigation assessments, and Low Emission Development Strategies (LEDS), particularly in developing countries, and many countries have chosen to use LEAP as part of their commitment to report to the United Nations Framework Convention on Climate Change (UNFCCC) (Heaps, 2021).

LEAP and the training materials and documentation that go with it are free to eligible academic and governmental organizations in impoverished countries, as well as students all across the world. SEI's COMMEND program, an online endeavor to build a community among developing nation energy analysts, distributes and supports LEAP. An integrated approach to planning, a robust decision support system, support for numerous approaches, a focus on scenario analysis, and cheap initial data requirements are just a few of the highlights of LEAP (Heaps, 2021).

The Low Emissions Analysis Platform (LEAP) is an energy-environment modeling tool based on scenarios. Its scenarios are based on a detailed analysis of how energy is consumed, transformed, and produced in a given region or economy under a variety of different populations, economic development, technology, pricing, and other assumptions. LEAP's configurable data formats enable users to conduct analyses with as many technical specifications and end-use details as they want (Heaps, 2021).

The user can utilize LEAP to create complex simulations and data structures in addition to simple accounting. LEAP does not aim to estimate the impact of energy policies on employment or GDP, unlike macroeconomics models, though such models can be used with LEAP. Similarly, while LEAP can identify least-cost situations, it does not automatically create optimum or market-equilibrium scenarios. The flexibility and ease of use of LEAP are significant advantages, allowing decision-makers to move quickly from policy concepts to policy analysis without resorting to more sophisticated models (Heaps, 2021).

LEAP serves many purposes: as a database, it provides a complete system for storing energy data; as a forecasting tool, it allows users to generate long-term projections of energy supply and demand; and as a policy analysis tool. It models and evaluates the physical, economic, and environmental consequences of alternative energy plans, investments, and actions (Heaps, 2021).

LEAP can be used to forecast future energy supply and demand trends, identify potential problems and assess the anticipated effects of energy policy. LEAP can help you evaluate a wide range of projects, programs, technologies, and other energy activities to determine the best approach for addressing environmental and energy issues (Heaps, 2021).

2.3.1 Views

The Analysis View

This is where you create data structures, models, and assumptions in LEAP. In the Analysis view, the screen is divided into three panes. The data structure on the left is generated and organized using a hierarchical tree and it is separated into four key categories: Key Assumption, Demand, Transformation, and Resources. The tree can also be used to select the data that has to be changed from the right-hand side of the screen. The top-right corner of the screen has a data entry table that is used to alter data and build modeling relationships. In the bottom-right pane, the data you enter is graphically displayed.

The result View

It provides precise information on each component of the energy system. It can be used to create a wide range of graphs and tables that cover every aspect of the energy system, such as demand, transformation, resources, costs, and environmental loading.

The report can be customized in several ways and seen for one or more scenarios. You can also save the most relevant charts for analysis using the "Favorites" option.

2.4 Methodology

The research project is divided into four primary sections: 1) Data on energy was gathered from the concerned departments e.g., NEPRA, HDIP, Labor Department Khyber Pakhtunkhwa, and OGDCL. Crops area cover and production data was obtained from the Pakistan Bureau of Statistics. 2) Energy supply, demand, and consumption of various types of energy in various sectors and greenhouse gas emissions from these sources of energy, greenhouse gas emissions from these sources of energy, and greenhouse gas emissions from these sources of energy were analyzed forecasted. 3) Satellite Imagery of Sentinel-2 was acquired to calculate NDVI, extract bare land, and estimate biomass and utilize several indices such as NDVI, DBSI, and LAI. 4) Developing alternative scenarios for renewable energy supply and analyzing their influence on energy demand and GHG emissions was developed using biomass as a source of energy.

Step 1: This step entails gathering information on various types of energy from various sources, including electricity, fuel oil, natural gas, coal, and LPG from NEPRA, OGDCL, SNGPL and HDIP for the years 2012 and 2017. For energy analysis and GHG emission estimation, we used Compound Annual Growth Rate (CAGR) of five years (2012-2017) and IPPC Tier 1 calculations inbuilt in LEAP model data on data acquired. Sentinel-2 images are obtained from the Copernicus website for several dates to estimate biomass using equations.

Step 2: Various types of energy resources, including electricity, fuel oil, natural gas, coal, and LPG, were analyzed for supply, demand, and production, as well as their energy generating capacity, in this step. The present rate of growth is also used to forecast energy consumption. The amount of greenhouse gases created by burning fossil fuels for energy is also calculated. The current rate of increase in fossil fuel usage is also used to forecast GHG emissions.

Step 3: Satellite imagery was preprocessed to eliminate any discrepancies that could affect or render the results. The image was clipped to extract the area of interest, and different indices were used to estimate biomass. The indices include the Normalized Difference Vegetation Index (NDVI) for vegetation cover, the Dry Bareness Index (DBSI) for identifying bare land, and the Leaf Area Index (LAI) for calculating the leaf area per unit ground surface area.

Step 4: In the final stage, energy output from the computed biomass is projected, and an alternative renewable energy production scenario is created in the LEAP model. The biomass energy was assumed to generate electricity and the amount of electricity produced by this biomass energy was estimated. Moreover, its impact on electricity production was observed relating to the supply and demand under reference scenario as well as GHG emissions from this electricity production were analyzed and predicted in the future.

2.4.1 Demand Analysis

Electricity data from various sources for 2016-2017 was fed into the LEAP model under the Demand tree. In Khyber Pakhtunkhwa, the data is for several consumer sectors. Domestic, commercial, industrial, agricultural, lighting, bulk supplies, and other government uses are covered. Two companies provide electricity for home use: Peshawar Electric Supply Company (PESCO) and Tribal Areas Electric Supply Company (TESCO). PESCO has 2,805,420 registered domestic electricity consumers, with a compound annual growth rate of 3.47% and an average yearly usage of 1,740.49 kilowatt-hour per household per year, with a growth rate of 1.28%. The total number of domestic customers registered with TESCO is 402,521, with a compound annual growth rate of 0.11% and an average yearly usage of 2,528.29 kilowatt-hour per household with a 3.85% drop rate. Similarly PESCO has 321,802 registered electricity consumers for business purposes, with a compound annual growth rate of 3.58% and an average annual usage of 2,298 kilowatt-hour per household, up 3.96%. TESCO has 28,382 registered commercial users, with a compound annual growth rate of 0.22% and an average yearly electricity demand of 241.70 kilowatt-hours, down 6.77%. As companies utilize energy extensively, the number of users registered with PESCO for industrial use is 32,023 with a compound annual growth rate of 2.54% and an average yearly usage of 66,561 Kilowatt-hours with a 0.51% increase rate. TESCO has 4,236 industrial units registered, with a compound annual growth rate of 1.22% and an average yearly usage of 34,292 kilowatt-Hour, representing a very high increase rate of 34.72%. Electricity makes a significant contribution to agriculture. PESCO has 23,289 registered agriculture units with a compound annual growth rate of 0.06% and an average annual consumption of 3,568 kilowatt-hour per unit with a decrease rate of 7.09%, while TESCO has 6,741 units with a 5.76% annual decrease rate and an average annual consumption of 7,375.76 kilowatt-hour per unit with an increased rate of 4.93%. The lighting of roads and streets consumes a significant amount of electricity. PESCO has 1,088 connections, which is increasing at a rate of 1.80%, and an average yearly consumption of 12,169 kilowatt-hour, which is declining at an 11.64% rate. There is no road or street lighting in the Federally Administered Tribal Area. Bulk Supply is another mode of energy use, with 904 consumers registered with PESCO, a rise of

0.76%, and an average yearly consumption of 641,261 kilowatt-hour per unit, up 0.97%. TESCO provides energy to 61 Bulk Supply units, up 2.62%, and the average yearly consumption of a single unit is 124,590 kilowatt-hour, up 3.37%. Large government organizations consume a significant quantity of electricity. PESCO delivers energy to 48 government units, increasing at a rate of 1.06% every year, with each unit's average yearly demand of 45,625 kilowatt-hours increasing at a rate of 1.72%. TESCO does not offer electricity to any government agencies.

Fuel oil data from several sources for 2016-2017 was put into the LEAP model under the demand tree. Data on oil usage in Khyber Pakhtunkhwa was acquired for a variety of sectors. Domestic, industrial, agricultural, transportation, electrical generation, and government organizations were all represented. The total average domestic fuel oil consumption is roughly 6,641 Tons of Oil Equivalent (TOE), which is falling at a pace of 4.32%. Oil serves as a production backbone for many sectors. With a compound annual growth rate of 17.40%, industrial fuel oil usage reached 109,897 Tons of Oil Equivalent (TOE). As Pakistan is an agricultural country, and most people in Khyber Pakhtunkhwa choose agriculture as a profession, there is enough oil usage in the agricultural sector, with an annual average of 668 Tons of Oil Equivalent (TOE) and a high increase rate of 65.61%. Oil is mostly used in the transportation sector. The importance of a country's communication network cannot be overstated. The average amount of fuel oil utilized for transportation in KP is 1,398,964 Tons of Oil Equivalent (TOE), up 1.58% annually. Pakistan's primary concern today is power generation. Electricity demand is growing by the day, and meeting it, fossil fuels are being used to generate electricity. The amount of oil consumed for electricity generation was around 1,360 Tons of Oil Equivalent (TOE), which is down 5.03%. Government organizations have an essential role in creating policies and management, which determines the country's success. Large organizations require oil to meet their basic demands. The estimated oil usage of the concerned sector is 73,116 Tons of Oil Equivalent (TOE), which is increasing at an alarming pace of 11.55% per year.

Natural Gas usage data for 2016-2017 was gathered from the relevant departments and entered into the LEAP Model under the demand tree. Domestic, commercial, industrial, and transportation sectors were recognized as contributing to natural gas use. Natural gas use at the domestic level is critical since it provides a means to meet basic needs and maintain daily routines. According to SNGPL and SSGCL, registered domestic users numbered 716,539 with a compound annual growth rate of 6.6%, while average annual consumption was estimated to be around 41,596 CFt per household with a declining rate of 11.20%. The number of commercial natural gas consumers registered with the concerned authority in Khyber Pakhtunkhwa is 8,725, with a 0.1% decline rate and yearly consumption of roughly 270,945 CFt per building with a 2% decrease rate. In Pakistan, natural gas is mostly used in the industrial and transportation sectors. Natural gas availability is critical to the industrial sector. SNGPL, SSGCL supplies natural gas to 850 industries, with a compound annual growth rate of 0.5% and the average amount of natural gas consumed by a single unit is around 16,848,235 CFt, an annual reduction of about 1.80%. Almost all vehicles use natural gas as a fuel in the form of compressed natural gas (CNG), which accounts for a substantial portion of natural gas use. The predicted average amount of natural gas consumed by the transport sector in Khyber Pakhtunkhwa is 25,094 Million CFt per year, up 2.35% over the previous year. This demonstrates the dire state of natural gas consumption for transportation.

Propane (C_3H_8) and Butane (C_4H_{10}) are used to make LPG. It is obtained as a co-product of crude oil processing at refineries or byproduct of natural gas extraction from oil and gas fields. Propane and Butane are both gases at room temperature, but they can be liquefied at low pressures and temperatures. LPG can also be kept securely and readily at room temperature. LPG is mainly used in the domestic, commercial, and industry. LPG use in Khyber Pakhtunkhwa is expected to be 67,803 tons, according to data collected from the Oil and Gas Regulatory Authority (OGRA). The compound annual growth rate has increased at a startling rate of 14.41%. In its stead, commercial use of LPG is also necessary. According to data, commercial LPG use is 14,018 tons with a 3.65% annual growth rate. LPG is increasingly being used in the industrial sector for a variety of reasons, including water heating, LPG-powered generators, and space heating. According to statistics, the amount of LPG used in the industrial sector is 10,831 tons, increasing 37.93%. As a result, LPG usage in the industrial sector is growing more popular than other energy sources.

Coal is a significant source of thermal energy. In Pakistan, it is primarily utilized in brick kilns and cement plants. Depending on the calorific value of the coal, it is classified as lignite, bituminous, subbituminous, or anthracite. Even though Khyber Pakhtunkhwa produces a minor percentage of Pakistan's coal, the province has numerous coal-consuming enterprises, the most prominent of which are brick kilns and cement plants. According to data collected from the Labor Department of the Government of Khyber Pakhtunkhwa, the province has about 623 brick kilns, but active brick kilns account for over 65% of the total, implying that about 405 of them are operational on a year-round basis. The number of brick kilns is declining at a rate of 4.5% per year. The average coal usage per kiln is 1277.5 tons, with a 2.2% average decline rate. In Khyber Pakhtunkhwa, seven cement plants consume an average of 243,176 tons of coal per year, with a compound annual growth rate of 5.96%. Many more cement plants are being planned to be installed in the province, and permits have been given, which will significantly affect coal demand in Khyber Pakhtunkhwa. Coal is mined on a modest scale in the province, which necessitates coal imports from neighboring provinces.

2.4.2 Transformation Analysis

Energy and energy sources are delivered from the point of generation to the point of consumption using a variety of transmission and distribution methods. For example, electricity is transmitted via a variety of cables with varying voltage and current carrying capacity. Some electricity is lost during transmission and distribution, depending on the state of the lines. According to NEPRA, the infrastructure for transmitting and distributing electricity is very weak and ancient, resulting in a 24 percent loss of transferring electric power. It means that over a quarter of the energy produced is lost in power transmission and distribution. Natural gas is transported via pipelines from one location to another, so traveling a long distance will almost certainly result in gas loss owing to leaks and low-quality material pipes. According to SNGPL, around 15.1% of natural gas transported is lost in pipes due to various causes. Similarly, oil produced in various parts of Khyber Pakhtunkhwa is transported by tankers and delivered to consumers via pipelines. It also results in the loss of some oil along the way. The loss is projected to be 2.58% of overall oil production, according to OGRA. LPG, which is now a source of energy, is transported around the provinces via various modes of transportation, many of which have leaks and losses due to movement between cylinders. Report losses measured in LPG are 12.77%, according to OGRA. Because coal is in a solid condition, coal production is unlikely to be lost if appropriately handled.

To keep the wheel of life turning, electricity generation is critical. Electricity efficiency is a measure of a country's stability. Renewable energy resources, such as hydel power generation, are the primary source of energy production in Khyber Pakhtunkhwa. There are thirteen hydel power-producing units located on dams such as Tarbela Dam on the Indus River, Warsak Dam on the Kabul River, and others. Malakand III PEDO is situated on a canal that runs parallel to the Swat River. Khyber Pakhtunkhwa's overall energy generation capacity is around 4,208 Megawatts, with historical production estimated to be 17,940 Gigawatt-hours in 2016-2017. Tarbela is responsible for 83.9% of KP's total electricity production. The overall process efficiency is estimated to be 86.5%. In order to see the supply-demand nexus and analyze the electrical generation gap, the historical production of all units is taken into account.

Natural gas has always been the backbone of a country's development. Natural gas is used in practically every aspect of modern life. Because of the services it provides, it contribute to the prosperity of the population. Natural gas is produced in two methods in Khyber Pakhtunkhwa: associated and non-associated. The associated natural gas feedstock capacity is 1.68 million tons of oil equivalent per year, with historical production of 19085 tons of oil equivalent. In contrast, the non-associated natural gas feedstock capacity is 18.18 million tons of oil equivalent per year, with historical production of 3,798,024 tons of oil equivalent in 2016-2017. Non-associated natural gas accounts for 99.5% of overall output, while associated natural gas accounts for only 0.5%. The historical production of associated natural gas is declining at an alarming rate of 14.7%, implying that associated reserves are vanishing over time, whereas the discovery of non-associated reserves results in a 3.9% increase in natural gas production.

The amount of oil consumed by a country impacts its level of development. It also considers the country's economic standing around the world. Oil is one of the essential components in this competition. Nowadays, there is competition between countries worldwide for energy resources, and oil is one of the essential components in this battle. With a historical production of 2,282,575.47 tons of oil equivalent in 2016-2017, Khyber Pakhtunkhwa has a capacity of 26.60 million tons of oil equivalent per year. Geophysical surveys are being conducted in an attempt to identify oil deposits so that Pakistan can become a developed country. Oil output is currently expanding at a compound annual growth rate of 12.4%, causing oil reserves to deplete more quickly.

Hundreds of millions of people rely on LPG for various applications, including cooking, commercial business, industry, farming, and other uses. LPG is derived from crude oil and gas plants, which are the two primary sources of energy. LPG from crude oil has a feedstock capacity of 401,633 tons of oil equivalent per year and a historical production of 34,464 tons of oil equivalent per year, with a compound annual growth rate of 1.48%. Gas plants aid LPG generation. For 2016-2017, the historical production of LPG from gas plants in Khyber Pakhtunkhwa was 196,192 tons of oil equivalent, with a growth rate of 10.28% and a feedstock capacity of 1,100,869.98 tons of oil equivalent per year.

Coal is the most often used fuel and is the cheapest energy source among all fossil fuels. It is widely utilized as a fuel in coal-fired power plants all over the world.

However, the cement industry and brick kilns in Pakistan make extensive use of it. The cement sector consumes 68.8% of total coal usage in Pakistan, while brick kilns consume 25.5%. Khyber Pakhtunkhwa has a feedstock capacity of 671,100 million tons of coal equivalent per year and a historical production of 160,902 tons of oil equivalent, with a 1.9% annual growth rate. It signifies that coal reserves are rapidly depleting, resulting in problems with coal supply to consuming units, necessitating the purchase of coal from neighboring provinces.

2.4.3 Seasonal Crops NDVI Analysis

Rectified images were evaluated for the development of spectral indices. The VIs were generated from Sentinel-2 image spectral bands using ArcMap 10.5 raster calculator. Vegetation indices emphasize the vegetated area in a picture and can thus be used for vegetation mapping and monitoring. The canopy leaf area affects the sensitivity of broadband vegetation indices. Since they employ the near-infrared (NIR) spectral band, which has a high reflectance of vegetation, and the red spectral band, which has a high absorption by vegetation, the indices are used for vegetation monitoring. They are indications of healthy photosynthetic activity. It is used to determine the quantity and vigor of biomass. Plants absorb photons, energy packets with a red wavelength during photosynthesis and reflect the most in the infrared region from the mesophyll tissues in leaves. In sentinel-2, Band 4 is red, and Bands 8 and 8A are NIR bands. There are approximately 150 vegetation indices, but NDVI was chosen for preliminary investigations because of its success in assessing biomass and mapping vegetation. The NDVI is one of the broad Vegetation Indices (Eq. 1). One of the most widely utilized VIs for biomass estimation is NDVI (Rouse et al., 1974). It has been proven to have a reasonable association with biomass depending on the vegetation cover in prior studies. Equation of NDVI is given as;

$$NDVI = (NIR - Red) / (NIR + Red) \qquad (1)$$

Where: NIR is of 842nm wavelength, spectral band 8, while the red is spectral band 4 of 665nm wavelength of Sentinel-2 satellite imagery.

The results of the testing of the standard bare soil index (NDBaI) revealed that bare soil has a lower mean NDBaI than built-up areas, indicating that this index was unable to detect bare soil in the study area effectively. The DN of bareness and built-up classes varies throughout bands. Inspection of the bands revealed that spectral values in the SWIR1 and green bands might be used to differentiate these groups (Eq. 2). The DN of bare land is often slightly more significant than the DN of the built-up class in these bands (Xu, 2006).

Equation of DBSI is given as;

$$DBSI = (SWIR1 - Green) / (SWIR1 + Green) - NDVI \qquad (2)$$

Where: SWIR is 1.610nm, spectral band 11, while Green is spectral band 3 of 0.560nm wavelength of Sentinel-2 satellite imagery.

Vegetation's biophysical and biochemical characteristics are frequently measured to determine its photosynthetic capability, physiological status, and developmental stages. Understanding agricultural ecosystems require spatially explicit information of vegetation traits. For various objectives, scientists have presented several definitions of LAI from a variety of disciplines (Clevers & Gitelson, 2013). The Leaf Area Index (LAI) is a biophysical variable that substantially affects canopy microclimates, water balances, gas exchanges, and plant photosynthetic efficiency (Eq. 3). LAI has a solid link to canopy formation, biomass, light interception, and yield (Ali & Imran, 2020). Green leaves selectively absorb solar radiation, have a high absorption of visible light, and absorb far more red light than infrared light, allowing vegetation indices to be generated (Zheng & Moskal, 2009). LAI can be calculated using NDVI of the plants by using the following formula.

$$LAI = [NDVI * (1 + NDVI) / (1 - NDVI)]0.5 \qquad (3)$$

Many agricultural, ecological, and meteorological applications require accurate assessment of vegetation biochemical and biophysical characteristics. Three of these variables; Leaf Area Index, height, and biomass, can be used to define plant architecture, track canopy structure changes, and forecast growth and yield (Dente et al., 2008). Remote sensing is the only viable method for estimating these variables over wide areas because it can collect data at a regional and global scale (Eq. 4). The primary factor affecting the spectral reflectance of vegetative canopies in the visible and near infrared (NIR) spectrum is plant stand architecture. There is a strong relationship between these factors and spectral vegetation indices (VIs) based on various wave reflectance combinations. Different indices, such as the Leaf Area Index (LAI), and various biophysical characteristics, such as the average height of the crops, can be used to compute biomass (Eq. 5). Below are the equations that relate the above parameters (Gao et al., 2013).

$$Biomass = 1.01 * height * exp(1.05 * LAI) \qquad (4)$$

Where; height is the average height of the crop and LAI is the Leaf Area Index of the crop and;

$$Biomass\ (Mg\ ha - 1) = 10N * (100 / S) * BW / 1000 \qquad (5)$$

Which can be simplified to;

$$Biomass\ (Mg\ ha - 1) = N * BW / S \qquad (6)$$

Where N is the number of plants in a continuous row of 100 meters, S represents the distance between rows in the field, and BW denotes the average plant biomass weight calculated using the best allometric equation (Eq. 7). The general allometric equations for all sugarcane cultivars are as follows (Eq. 8):

$$SFB = 0.046\, H * D1.567 \qquad (7)$$

and;

$$AB = 0.4001\, H * D1.0743 \qquad (8)$$

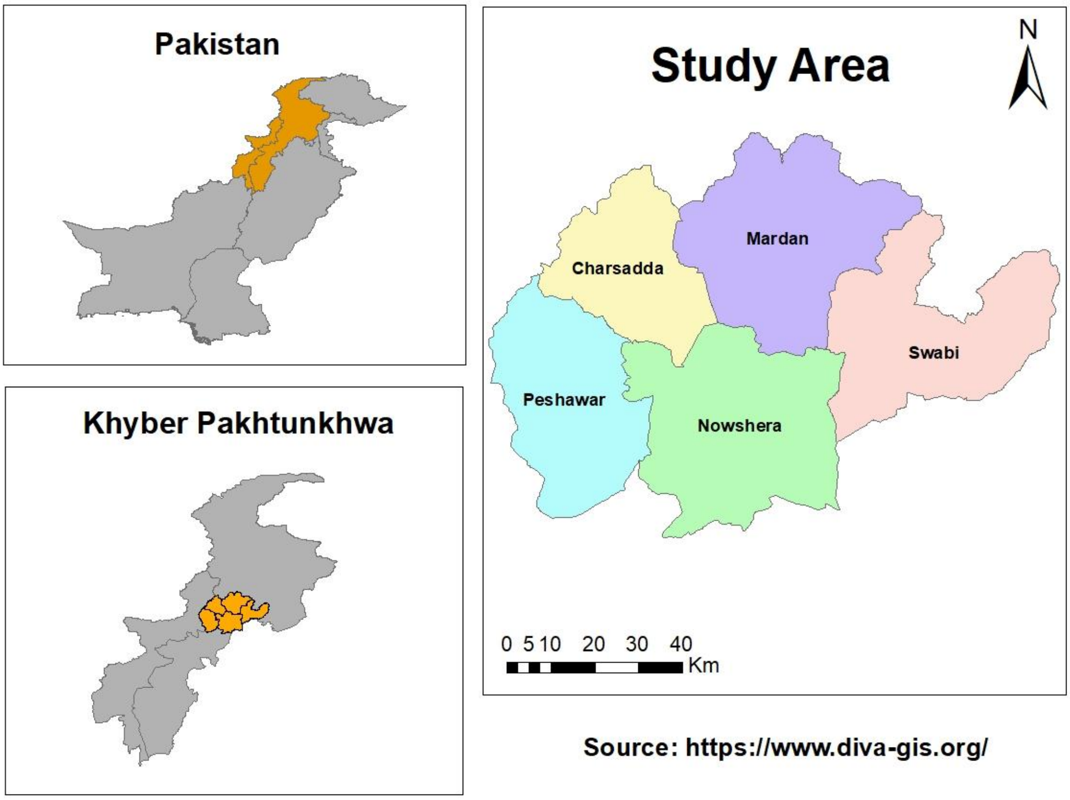


Figure 1. Map of the study area.

Table 1. List and description of the datasets used in the analysis

S. No.	Type	Description	Source
1	Electricity	Consumption in various sectors and generation data	NEPRA
2	Natural Gas	Consumption in various sectors and production data	HDIP
3	Fuel Oil	Consumption in various sectors and production data	HDIP
4	Charcoal	Consumption in various sectors and production data	HDIP
5	Biomass	Satellite imagery suitable for the detection of Vegetation and bare land	Sentinel-2 Satellite

Table 2. Spectral bands and resolution of Sentinel-2 Satellite

S. No.	Sentinel-2 Bands	Central Wavelength (µm)	Resolution (m)
1	Band1–Coastal aerosol	0.443	60
2	Band2–Blue	0.490	10
3	Band3–Green	0.560	10
4	Band4–Red	0.665	10
5	Band5–Vegetation Red-edge	0.705	20
6	Band6–Vegetation Red-edge	0.740	20
7	Band7–Vegetation Red-edge	0.783	20
8	Band8–NIR	0.842	10
9	Band8A–Vegetation Red-edge	0.865	20
10	Band9–Water Vapor	0.945	60
11	Band10–SWIR–Cirrus	1.375	60
12	Band11–SWIR	1.610	20
13	Band12–SWIR	2.190	20

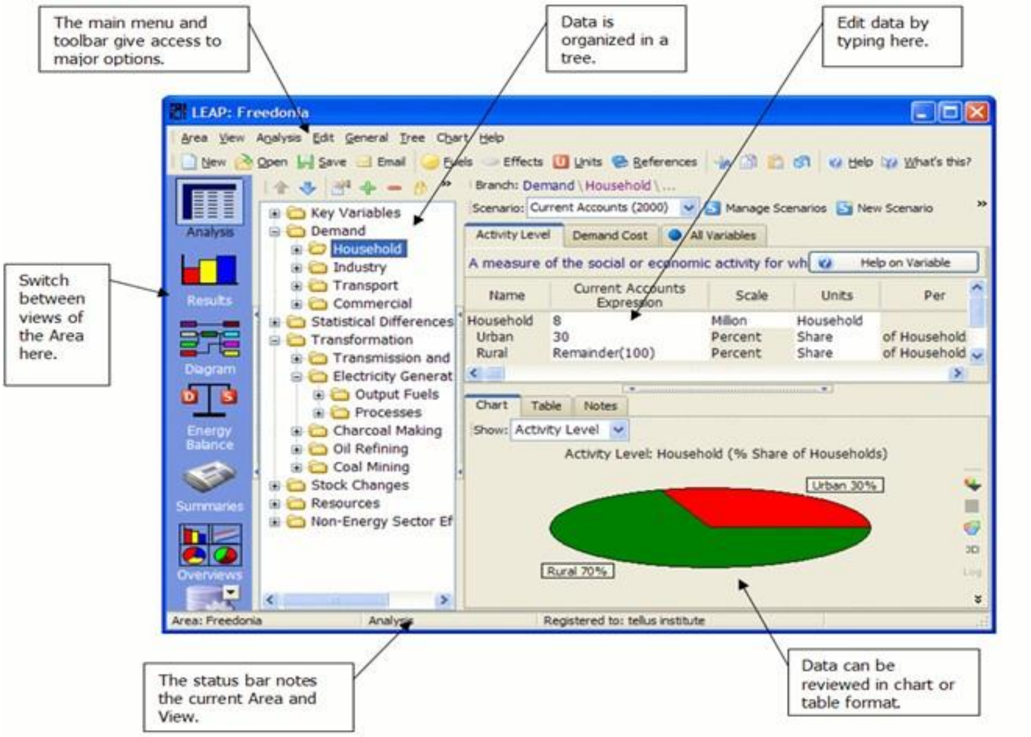


Figure 2. The general user interface of LEAP model.

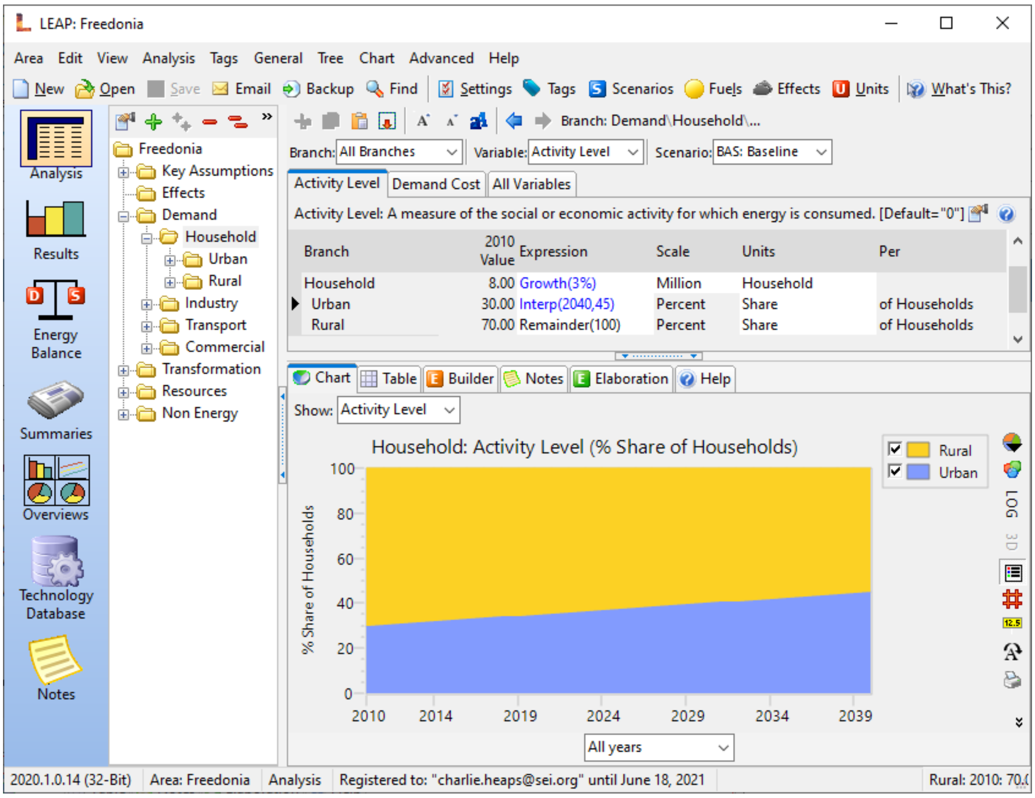


Figure 3. The general user interface of Analysis view in the LEAP model.

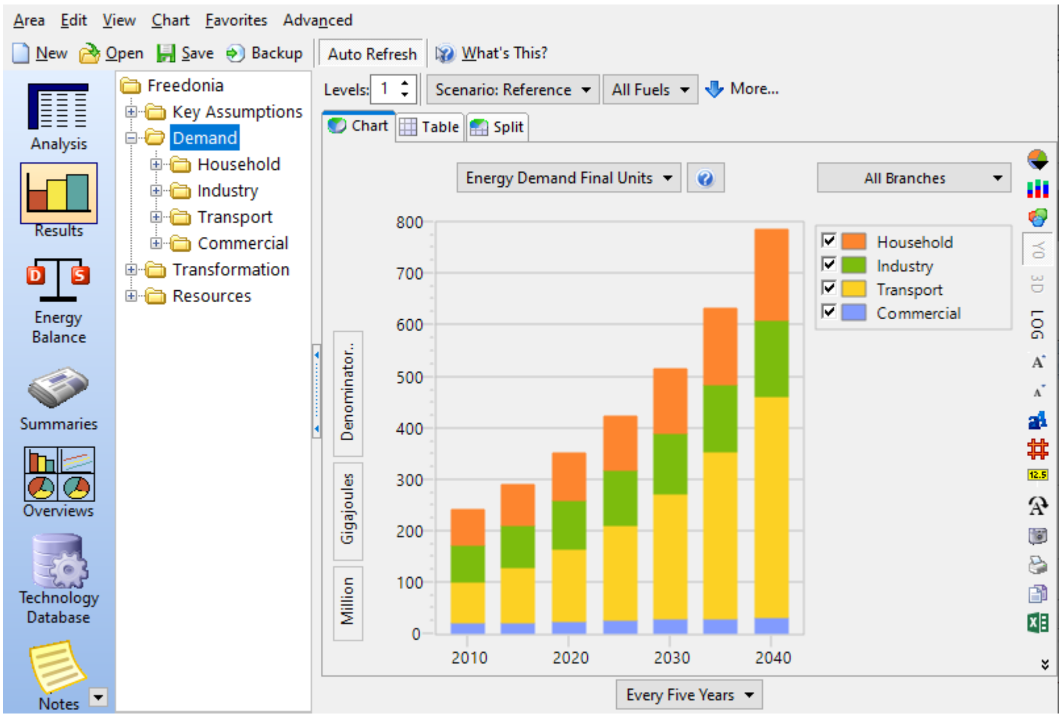


Figure 4. The general user interface of results view in the LEAP model.

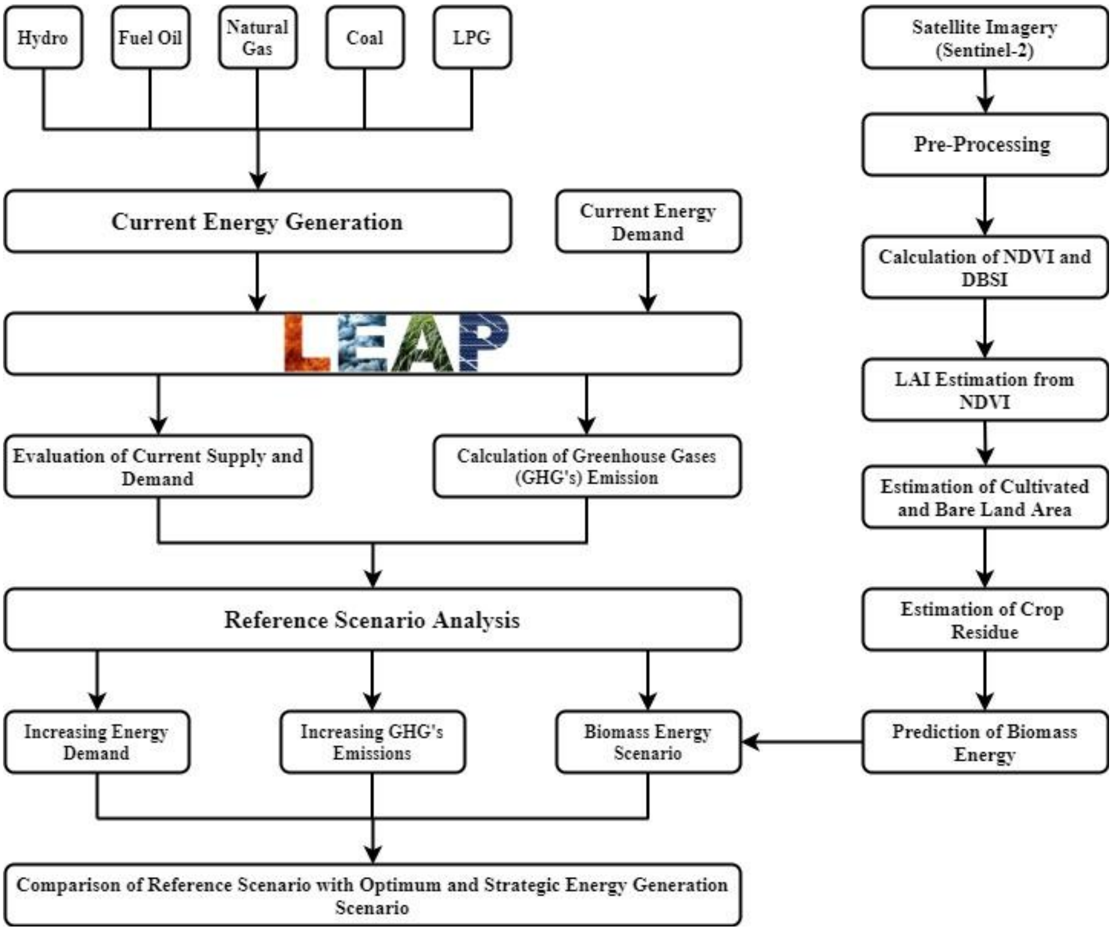


Figure 5. Methodology flow chart of the study.

Chapter 3

RESULTS AND DISCUSSIONS

3.1. Reference Scenario Analysis

3.1.1 Energy Demand and Forecast Analysis

Data within the LEAP model was used to analyze energy demand and forecasts for various sources of energy consumption, including electricity, oil, natural gas, coal, and LPG, in a variety of sectors, including domestic, commercial, and industrial. Its main goal was to figure out how much of each form of energy is utilized in these sectors, as well as the rate at which demand is growing. Forecasting was done for each sector based on the current rate of increase in each form of energy in each sector from now until 2035. According to the analysis, electricity consumption is growing at a rate of 10.45% per year, with a peak demand of 4.97 million TOE in 2035. The cause for the rise in demand is the widespread use of modern technologies in all aspects of life, as well as the fact that the world's population is rapidly increasing, creating a demand for energy to meet people's basic requirements. Oil consumption is also rising at an alarming pace of 10.89%, implying that fuel oil demand would rise to 10.22 million TOE by 2035. Fuel oil is the most crucial ingredient in maintaining a mechanized lifestyle, which is being accepted by modern generations. Human life is assisted by transportation, which necessitates a large amount of fuel, and by a variety of other processes. Natural gas, which already has the largest consumption of all sources of energy in 2017 is growing at a rate of 2.31% and will reach 142.60 TOE in 2035. It might have a tremendous influence on natural gas reserves, which are depleting at an alarming rate. Due to a better cost-benefit analysis, a substantial amount of transportation has shifted to CNG, resulting in high demand. Coal consumption is increasing at a rate of 4.58%, implying a demand for 2.23 million TOE in the coal sector by 2035. The cause for this rise is that the world's population is rapidly expanding, resulting in urbanization, which necessitates a great amount of construction material. Since the scarcity of other fossil fuels such as natural and fuel oil has been recognized, there has been a significant increase in LPG demand. Because of the frequent availability of LPG for continuous operation, many domestic, commercial, and industrial activities have migrated to it. LPG demand is growing at a rapid pace of 23.81%, and it will reach 4.89 million TOE in 2035. Overall energy demand from various sources for various sectors is increasing at a rate of 2.93%, implying a requirement of 164.91 million TOE by 2035 (Fig. 6). It signifies that energy is crucial right now, since it serves as a backbone for the country's and nation's development and prosperity.

3.1.2 Electricity Demand and Forecast Analysis

In both firms, PESCO and TESCO, electricity demand and forecast analysis was performed on data using the LEAP model for various sectors of electricity consumption, including domestic, commercial, industrial, agricultural, public lighting, bulk supply, and government organizations. Its primary goal was to determine how much electricity is consumed in these industries and the rate at which demand is increasing. Forecasting was done for each sector based on the present pace of growth up to 2035. The analysis showed that registered users for domestic purposes would reach to the digits 5,183,900 in PESCO while in TESCO it will be up to 410,600 approximately. The annual electricity demand would increase to 2,188.3 kilowatt-hour per household in PESCO and decrease to 1,247.1 kilowatt-hour per household in TESCO for domestic purposes which shows that electricity demand will reach to

11.34 billion kilowatt-hours in PESCO and 0.51 billion kilowatt-hour in TESCO for foresaid purpose in 2035. Commercial users are expected to reach 606,100 in PESCO and 29,500 in TESCO keeping in view the current growth rate (Fig. 7). Electricity consumed per household annually in PESCO will increase to 4,623.2 kilowatt-hour and decrease to 68.4 kilowatt-hour in TESCO indicating that electricity consumption will be 2802.19 million kilowatt-hour in PESCO and 2.02 million kilowatt-hour in TESCO for commercial usage by 2035. Industries are increasing day by day, which has huge impact on electricity consumption. Industrial unit will cross the digit 50,300 in PESCO and 5,300 within TESCO with respect to current growth rate. The annual usage of electricity will reach to 72.9 thousand kilowatt-hour for PESCO and 7,327.7 thousand kilowatt-hour per industrial unit in TESCO. The electricity consumption for PESCO is expected to be 3.67 billion kilowatt-hour and 38.61 billion kilowatt-hour for TESCO industrial users for the year 2035. Switching to electricity from manual and other forms in Agriculture is the aim of the developing world. Agriculture units registered with PESCO are going to increase to 23,500 and decreasing to 2,300 in TESCO. Annual average consumption of PESCO is estimated to decrease to 900 kilowatt-hour and increase to 17,500 kilowatt-hour per connection. The consumption of electricity in the agriculture sector is approximated 42.36 million kilowatt-hour in PESCO and 40.64 million kilowatt-hour in TESCO until 2035. Electricity is provided to public light all over the province to ease the communication and other purposes. PESCO users for public lighting is going to increase to 1500. TESCO is supplying electricity to backward areas and there is no public lighting units. The annual average consumption by PESCO registered units is deemed 1300 kilowatt-hour every lighting unit. The electricity consumption in public light will get the measure of 1.97 million kilowatt-hour by 2035. Bulk supplies registered with PESCO for the consumption of electricity is going to reach 1,036 and 97 with TESCO. Average annual electricity consumption of each supply unit with PESCO will be 763 thousand kilowatt-hour and 226.2 thousand kilowatt-hour of each TESCO inscribed unit. The government organizations registered with PESCO will outstretch to 58 units and no organizations are recorded with TESCO supply. The average annual electricity consumption by each organizational unit will be 62 thousand Kilowatt-hour and electricity consumption will appear 3.59 million kilowatt-hour by 2035 (Fig. 8).

Electricity consumption identifies the developmental journey of a nation especially from the economic point of view. The fluctuations in the demand of electricity in various sectors determines the molding of the society and trends towards technological development in a nation. The increase of domestic users in both PESCO and TESCO reveal that population is increasing with an alarming rate that is resulting in urbanization due to accommodation problems. Secondly, the electricity is being supplied to the very backward areas of the province to ease their life. Keeping in view the increase in population and urbanization there is demand to fulfill their needs in the form of commodities resulting in rise of commercial activities. Industrial revolution has changed the world due to the advancement in technological evolution for meeting the needs of every aspect of life. The vigorous demand of technology has resulted in uncontrolled increase in industrialization. As Pakistan is an agricultural country, therefore more concentration is being given to mechanize the agricultural activities. It will help in easing the agricultural workflow and scientifically approaches made for increasing the yield. Khyber Pakhtunkhwa is observing negative growth in this respect, which is resulting in the low yield of crops. The increase in urban sprawl results in extension of communication network throughout the area. Moreover, this network needs to illuminate for the easy transportation in night. However, the electricity consumption is being reduced due to shifting towards solar energy as well as low energy using devices. Overall demand and consumption of electricity is being increased in a way or another.

3.1.3 Oil Demand and Forecast Analysis

For several sectors of oil consumption, such as domestic, industrial, agricultural, transportation, power generation, and government organizations oil demand and forecast analysis was conducted utilizing data gathered using the LEAP model. Its main goal was to figure out how much oil was used in these sectors and how quickly demand was growing. Each sector's forecasting was based on the current rate of growth until 2035. The analysis showed that oil consumption for domestic purposes with current rate of increase is estimated to be 3 thousand Tons of Oil Equivalent in 2035. Decrease is being seen in the consumption of fuel oil for domestic usage because of introduction of renewable energy resources and other cheap sources of energy production such as solar energy and LPG. As industrialization is on its peak in Pakistan, therefore for running of machineries and other miscellaneous activities oil is needed. Oil consumption is expected to reach 1,972.48 thousand Tons of Oil Equivalent in 2035. The huge increase in oil demand is the indication of developed and developing nations. An exceptional and sudden increase of oil is notice in agricultural sector of Khyber Pakhtunkhwa. The mechanization of the mentioned sector needs a lot of oil for its operation. However, it has helped farmers enabling them to use advance agricultural technology. Oil consumption in agricultural sector may cross 5,868.18 thousand Tons of Oil Equivalent in 2035 keeping in mind the current growth rate. Transport being the key pillar contributing to the development and easing of life holds a large portion in the oil consumption. The amount of oil used in transportation will reach up to 1,855 thousand Tons of Oil Equivalent in 2035.

Although the oil is being replaced by CNG in most of vehicles due to cost analysis, yet there is a large use of fuel in the foresaid sector. That is why the increase rate is less compared to it should be. Electric power was used to be generated through combustion of oil in generators and other machineries in very near past and still it is used but it is also being replaced by CNG and other resources therefore, there is negative growth in this sector of consumption. It is indicated that oil consumption for power generation will come down to 536.9 Tons of Oil Equivalent by 2035. Government organizations use fuel oil as a source of energy for various purposes and there is an excessive increase in the use of fuel oil because of old-fashioned appliances and ways of energy production. The approximate consumption of fuel oil in government organization is 523 thousand Tons of Oil Equivalent in 2035 (Fig. 9).

3.1.4 Natural Gas Demand and Forecast Analysis

The data gathered from various sources, using the LEAP model was used to analyze natural gas demand and forecasts for various sectors of natural gas use, including domestic, commercial, industrial, and transportation. Its primary goal was to determine how much natural gas is consumed in these sectors and the rate at which demand is increasing. Forecasting was done for each sector based on the present pace of growth up to 2035. The analysis showed that registered users for domestic purposes would reach to the digits 2,264,000 in SNGPL approximately. The annual natural gas demand would decrease to 0.11 Tons of Oil Equivalent per household in SNGPL for domestic purposes that shows that overall natural gas demand will reach to 256,800 Tons of Oil Equivalent in SNGPL for foresaid purpose in 2035. Commercial users are expected to decrease to 8,569 keeping in view the current growth rate (Fig. 10). Natural gas consumed per household annually in SNGPL will also decrease to 4.4 Tons of Oil Equivalent indicating that overall electricity consumption will be 37,300

Tons of Oil Equivalent in SNGPL for commercial usage by 2035. Industries are increasing day by day, which has huge impact on natural gas consumption. Industrial unit will cross the digit 930 in SNGPL with respect to current growth rate. The annual usage of natural gas is estimated 282 Tons of Oil Equivalent per industrial unit for SNGPL. The overall natural gas consumption for SNGPL is expected to be 261,800 Tons of Oil Equivalent for industrial users for the year 2035. The amount of natural gas used in transportation will reach up to 142 Million Tons of Oil Equivalent in 2035 (Fig. 11). As the fuel oil is being replaced by CNG in most of vehicles due to cost analysis therefore there is a large increase growth rate seen in natural gas consumption for transportation. It is indicated that by rate at which natural gas consumption is increasing there will a huge deficiency in the supply sector of natural gas. Natural gas connections are being increased due to high population growth rate and urbanization. As there is a limited resource of natural gas, therefore pressure comes on supply side that results in unavailability of natural gas. Many of connections are facing gas shortage and there is a shift seen to LPG and wood burning. Commercial and industrial usage needs huge amount of energy and the shortage in natural gas supply badly effects the schedule of commercial activities and industrial production that has caused the decrease in the users as well as consumption of natural gas in both sectors.

3.1.5 Coal Demand and Forecast Analysis

For several sectors of coal consumption, such as cement industries and brick kilns, demand and forecast analysis was conducted using data gathered in the LEAP model. Its primary goal was to determine how much coal is used in these industries and at what rate demand is growing. Each sector's forecasting was based on the current rate of growth until 2035. Analysis showed that there are seven cement industries in

Khyber Pakhtunkhwa with an average annual consumption of coal touching the value 442.2 thousand Tons of Coal Equivalent each industry by 2035. The gross consumption coal in cement manufacturing is estimated to be 3,095.64 Tons of Coal Equivalent by 2035. Many other cement industries are planned to install and existing factories are increasing the production lines that will have a huge demand of coal for mentioned units. Another well-known sector for consumption of coal are brick kilns. Analysis indicate that number of average active brick kilns will decrease to 171 and average annual consumption is calculated to be 549.1 Tons of Coal Equivalent by 2035. It shows that net energy consumption of coal in brick kilns will be 93.84 thousand Tons of Coal Equivalent by 2035 (Fig. 12). The increasing trend of coal consumption in the cement industries is due to abrupt development in communication networks and infrastructure, which is yielding high demand of cement and other ingredients for the mentioned purpose. Decreasing number of brick kilns shows the shifting of modern world towards alternative construction material due to cost-benefit analysis, which in turn have effect on the coal consumption in brick kilns.

3.1.6 Liquefied Petroleum Gas (LPG) Demand and Forecast Analysis

The data for various consumption sectors including domestic, commercial, and industrial, was used to conduct a demand and forecast analysis for LPG using the LEAP model. Its primary goal was to determine how much LPG is utilized in these industries and the rate at which demand is increasing. Forecasting was done for each sector based on the present pace of growth up to 2035. It has been observed that there is unexpected increase in the use of LPG for domestic purposes. The approximated consumption of LPG for domestic purpose is 864.3 thousand Tons of Oil Equivalent by 2035. LPG is vastly used for commercial purposes also. The guessed amount of LPG consumption by 2035 for commercial due to unanticipated increase is 30.2

thousand Tons of Oil equivalent. Industries have been shifting from natural gas and fuel oil on to LPG hence an instantaneous increase in demand of LPG for industrial usage is seen. It is revealed that LPG consumption will reach to huge amount of 3,995.7 thousand Tons of Oil Equivalent by 2035 (Fig. 13). As there is shortage in the supply of natural gas on domestic level due to excessive demand and compression of gas molecules in winter season rendering the movement of gases to domestic users therefore, LPG is the most efficient way of energy production for domestic purposes. Industries use to have continuous processes of production that needs constant supply of energy. Hurdles in the natural gas and fuel oil supplies effects the production schedule of the industries therefore, they have been switching to use of LPG for the mentioned processes. LPG is the controlled and systematic way of energy production that have positive impact on industrial economics.

3.1.7 Transformation of Energy

Energy transformation analysis was done on the data obtained using LEAP model for various sources of energy generation as well as transmission and distribution losses that included electricity, oil, natural gas, coal and LPG. Transformation of energy is driven by the results of energy demand analysis in various sectors such as domestic, commercial, industries, and many more. Its major purpose was to know that how much a type of energy is needed in these sectors and the grow rate at which the demand is being increased. The forecasting for each sector was done on the current rate of increase or decrease in historical production and exogenous capacity of each type of energy up to 2035. The analysis showed that electricity generation should increase by 6.17% from 1.54 to 4.53 million TOE in 2035 according to resources availability to go through the increase in demand. It is because the electricity consumption is being increased in routine life and rapid growth in population as well.

Overall analysis of natural gas production shows that it will get decrease by 5.77% from 3.82 to 1.31 million TOE in 2035 because of the limited resources available and meeting the decreasing demand due to shifting to other resources of energy. Oil production is going to increase by 8.69% from 2.28 to 10.22 million TOE in 2035 due to vigorous mechanization of every field. The resources are depleted fast that will have a negative on production in the future. LPG production as by-product of crude oil and natural gas is observed to increase by 11.84% from 0.23 to 1.73 million TOE in 2035. The unexceptional increase in LPG production in due to its increasing demand because of shifting from other resources of energy due to hurdles in their continuous and efficient supply. The cost-benefit analysis of LPG have an edge on other fossil fuels. The exploitation of coal reserves is the need of day because most of coal is imported for various purposes in Khyber Pakhtunkhwa. The production of coal will have to increase by 15.73% from 0.16 to 2.23 million TOE in 2035. The increase in demand of coal in cement industry is the pushing the factor as cement consumption in urban sprawl due to increased population rate is the increasing. There will be losses in in the transmission and distribution of energy from one place to another. It is directly proportional to amount energy production. It is measured that electricity losses occurs at the rate of 10.45% from 0.83 to 4.97 million TOE in 2035 because of weird infrastructure and wire lines having a larger resistance in the form of internal friction. The losses in the natural gas transportation will decrease by 3.60% from 1.08 to 0.56 million TOE in 2035 due to decrease in the production of natural gas due to various factors. Oil losses have been increasing by 10.89% from 1.59 to 10.22 million TOE in 2035 for the reason of increasing demand in various sectors specifically industry and transport but more vibrantly in agricultural sector. As a solid material there is no loss noticed in the coal production. Losses in LPG have been noted increasing by terrible rate of 23.81% from 0.10 to 4.89 million TOE in 2035 (Fig. 14). The main reason behind these losses is huge increase in LPG use in various sector and shifting of LPG between cylinders. The more the usage of LPG the more the losses.

3.1.8 Transmission and Distribution Losses Analysis

Transmission and distributions losses were analyzed and forecasted on the data obtained using LEAP model for various sectors of energy production including electricity, natural gas and oil losses. Its major purpose was to know that how much energy and its resources is being lost in various sectors and the grow rate at which the losses is being increased. The analysis showed that electricity losses are the highest of all which accounts up to 24% and in 2035. It means that almost one-fourth of the electricity fed into transmission and distribution lines is lost. The main reason behind this is the poor infrastructure and aged wires network. Electricity loss is directly proportional to aging of wires. Secondly, there are long distances to be travelled by network that has huge impact on electricity loss, as resistance is directly proportional to length of the wire. Oil is distributed all over the country through tankers and occasionally through pipelines that act as mean of oil losses. According to OGRA, 2.58% of the oil production is lost in its transportation annually. The loss is due to the vehicles and pipelines leakages travelling large distances. As natural gas is consumption is very common everywhere and there is household basis provision that provides a way for the natural gas loss. As per SNGPL annual report, the 15.1% of the natural gas is lost during its transportation process (Fig. 15). It also refers to poor infrastructure of natural gas distribution. As there is no supposed loss in the coal production sector, therefore all resources act as energy production resource.

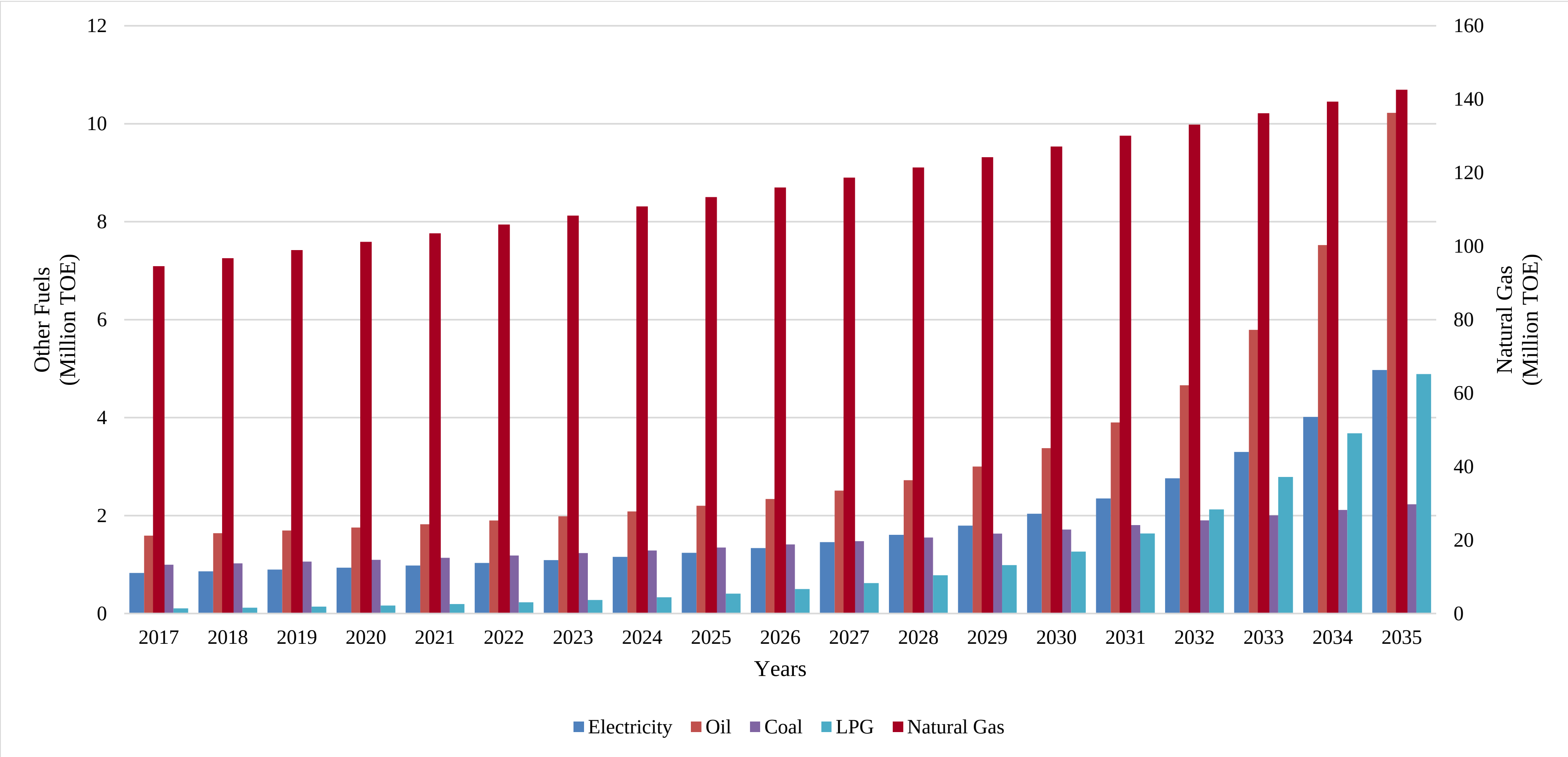


Figure 6. Estimated demand of energy from all types of fuels in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

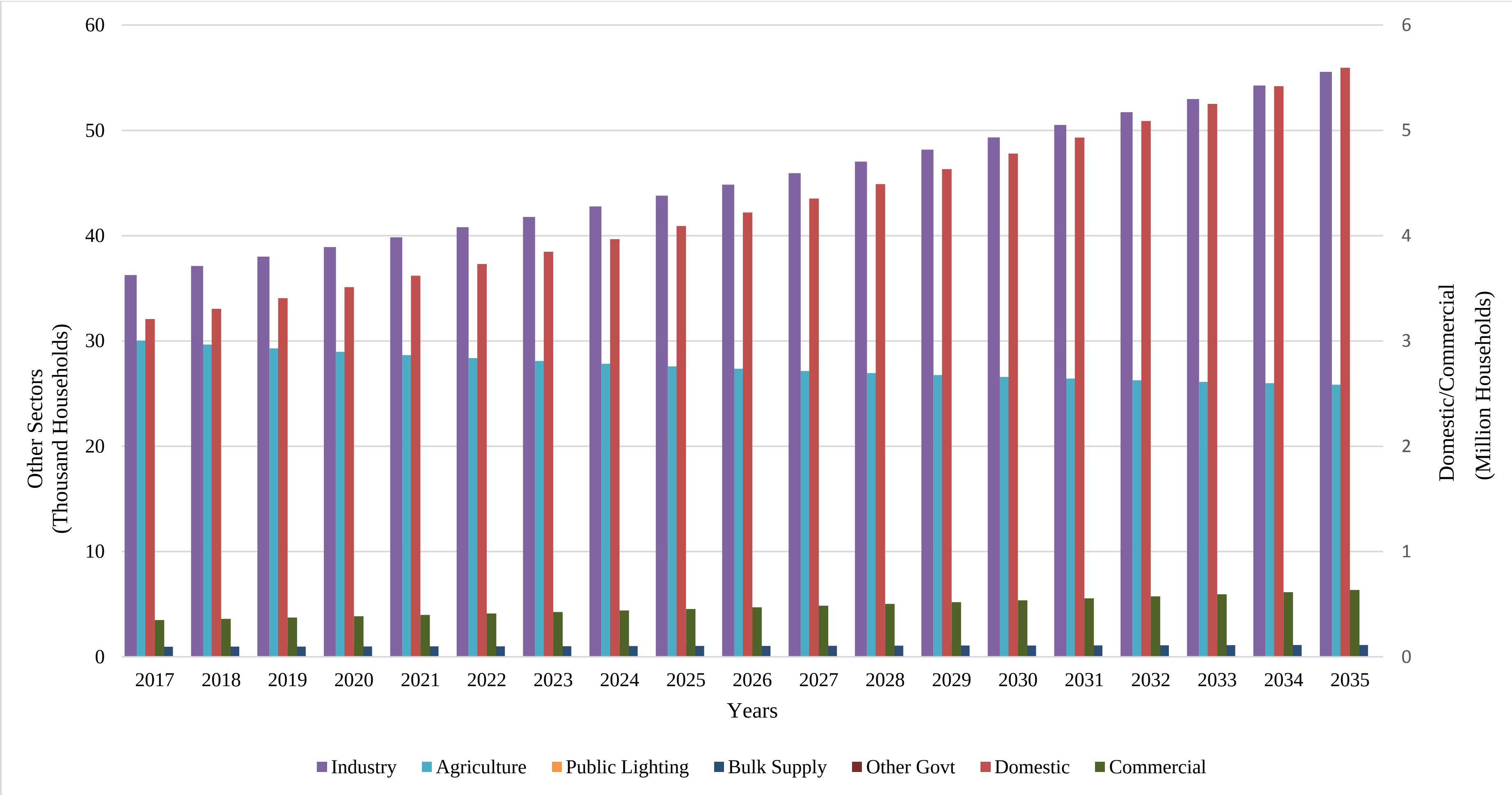


Figure 7. Estimated number of consumers in various sectors of electricity consumption in Khyber Pakhtunkhwa.

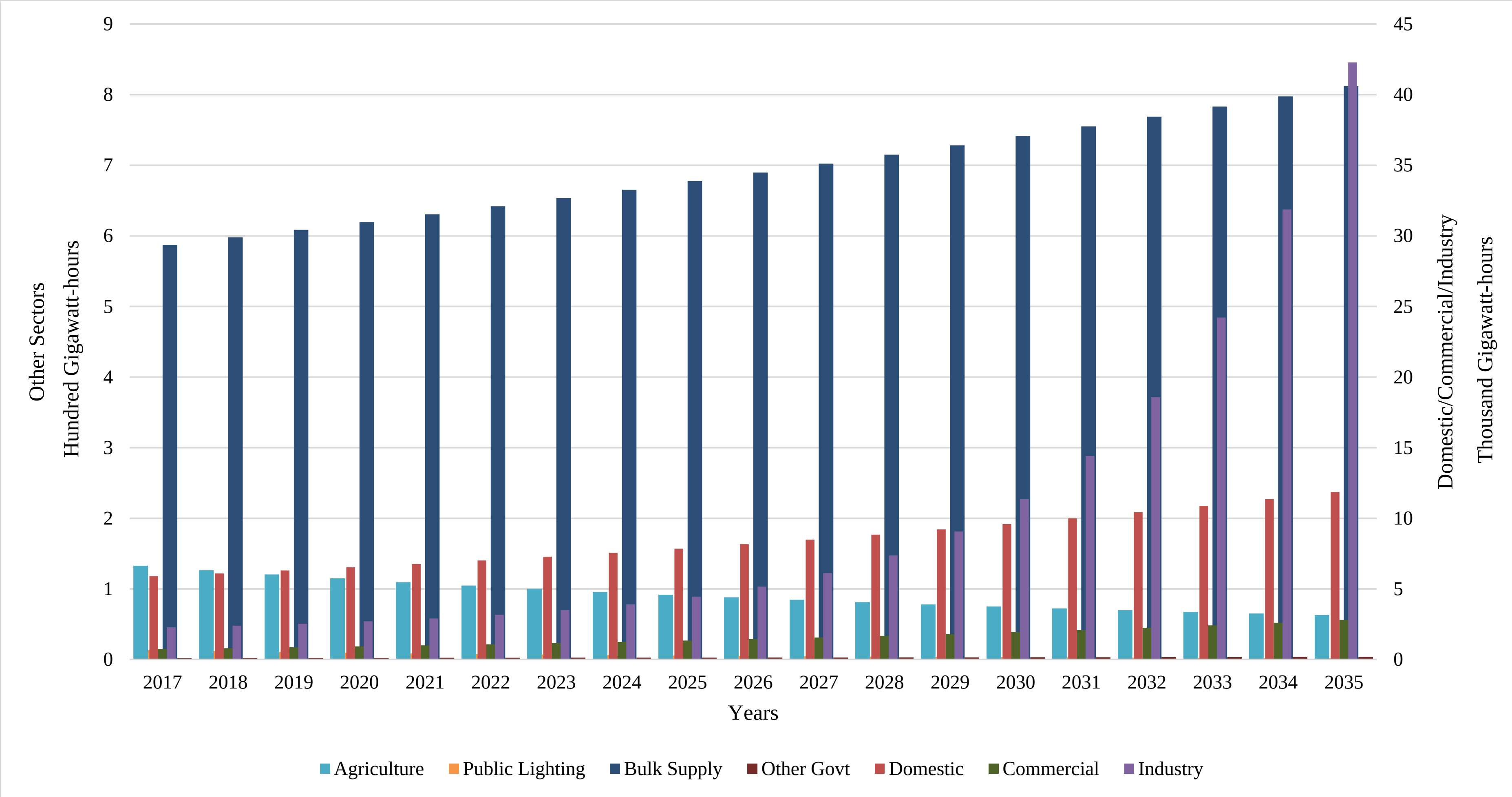


Figure 8. Estimated demand of electricity in various sectors of consumption in gigawatt-hours in Khyber Pakhtunkhwa.

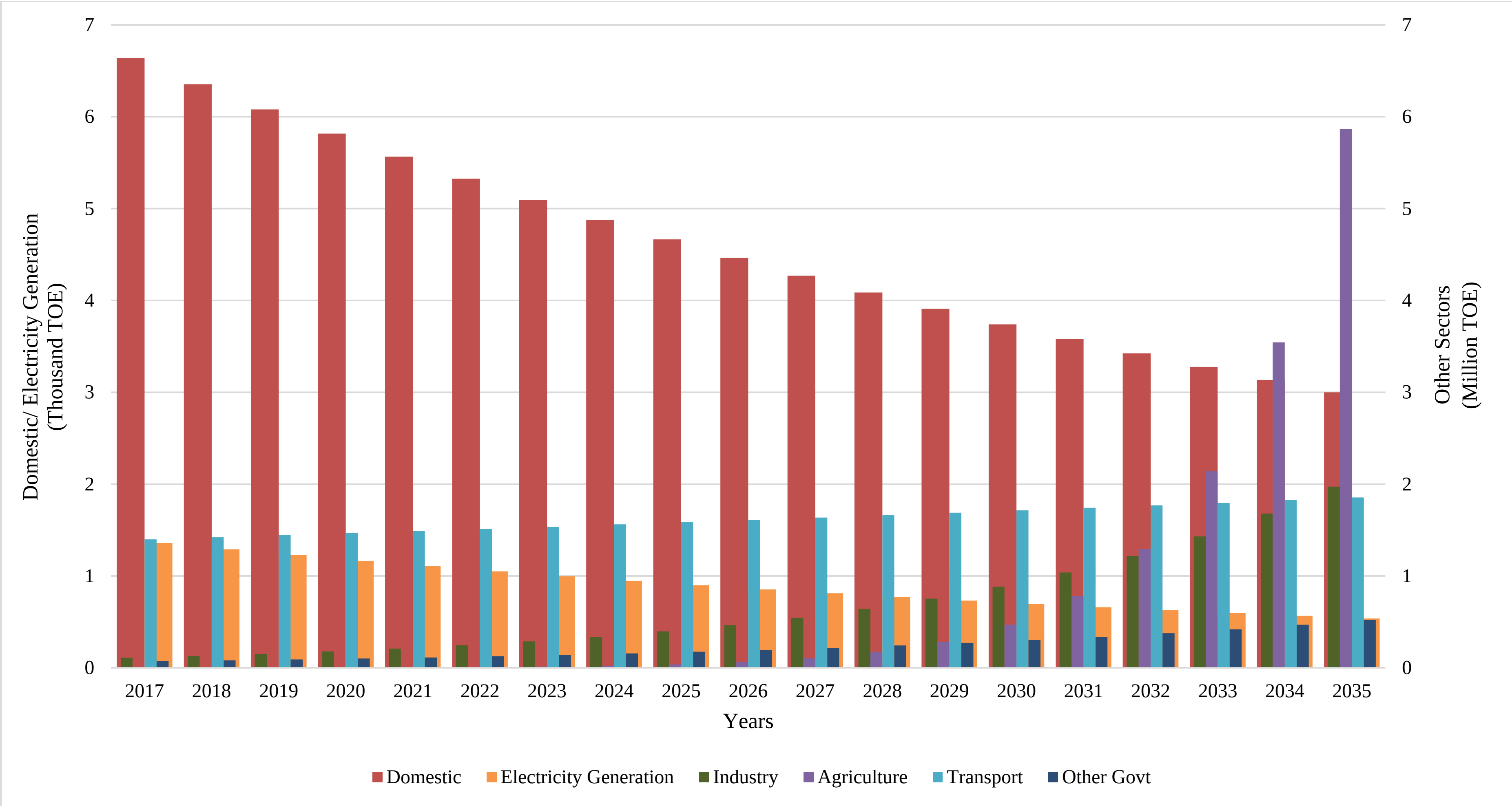


Figure 9. Estimated demand of fuel oil in various sectors of consumption in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

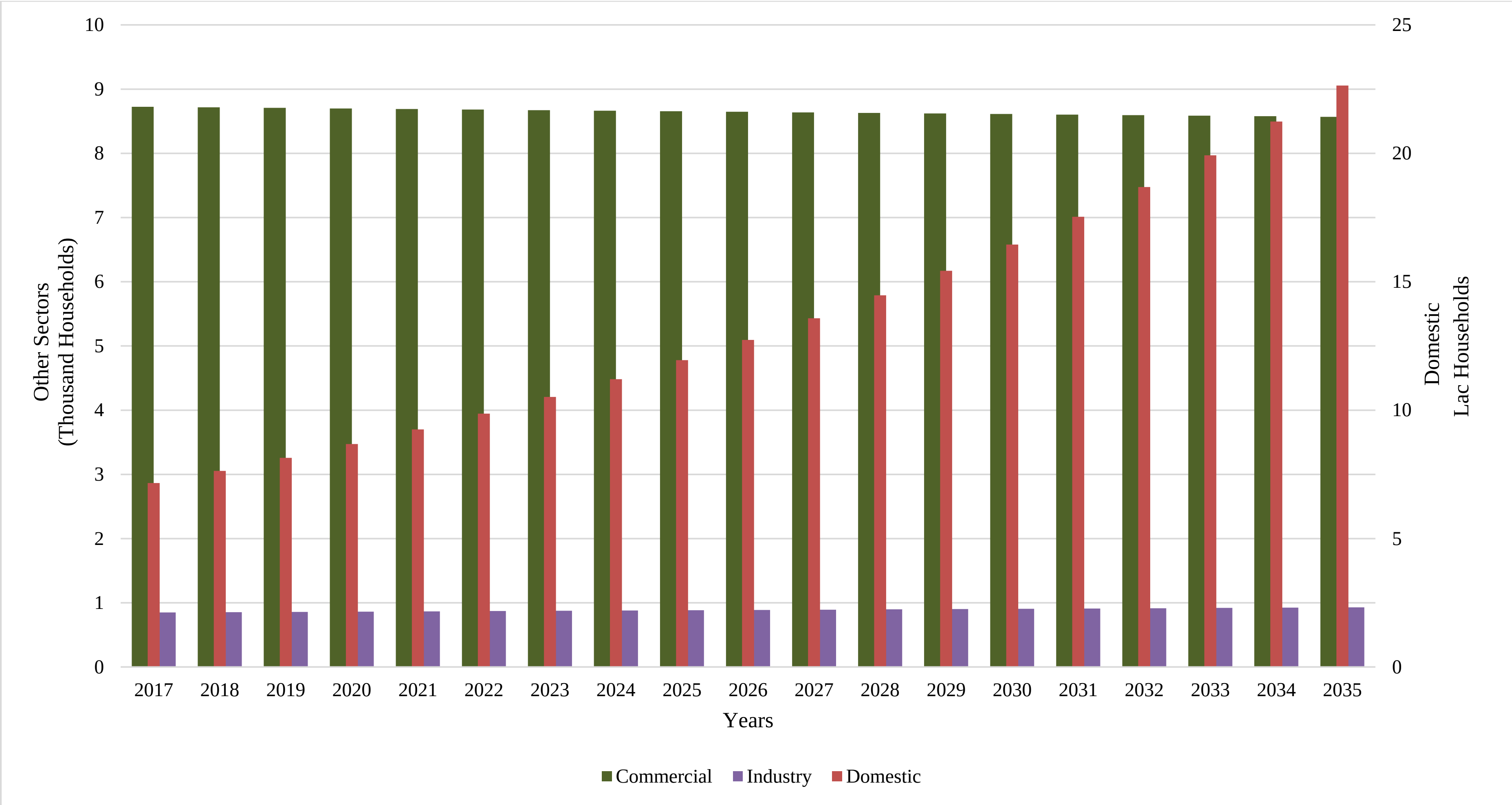


Figure 10. Estimated number of consumers in various sectors of natural gas consumption in Khyber Pakhtunkhwa.

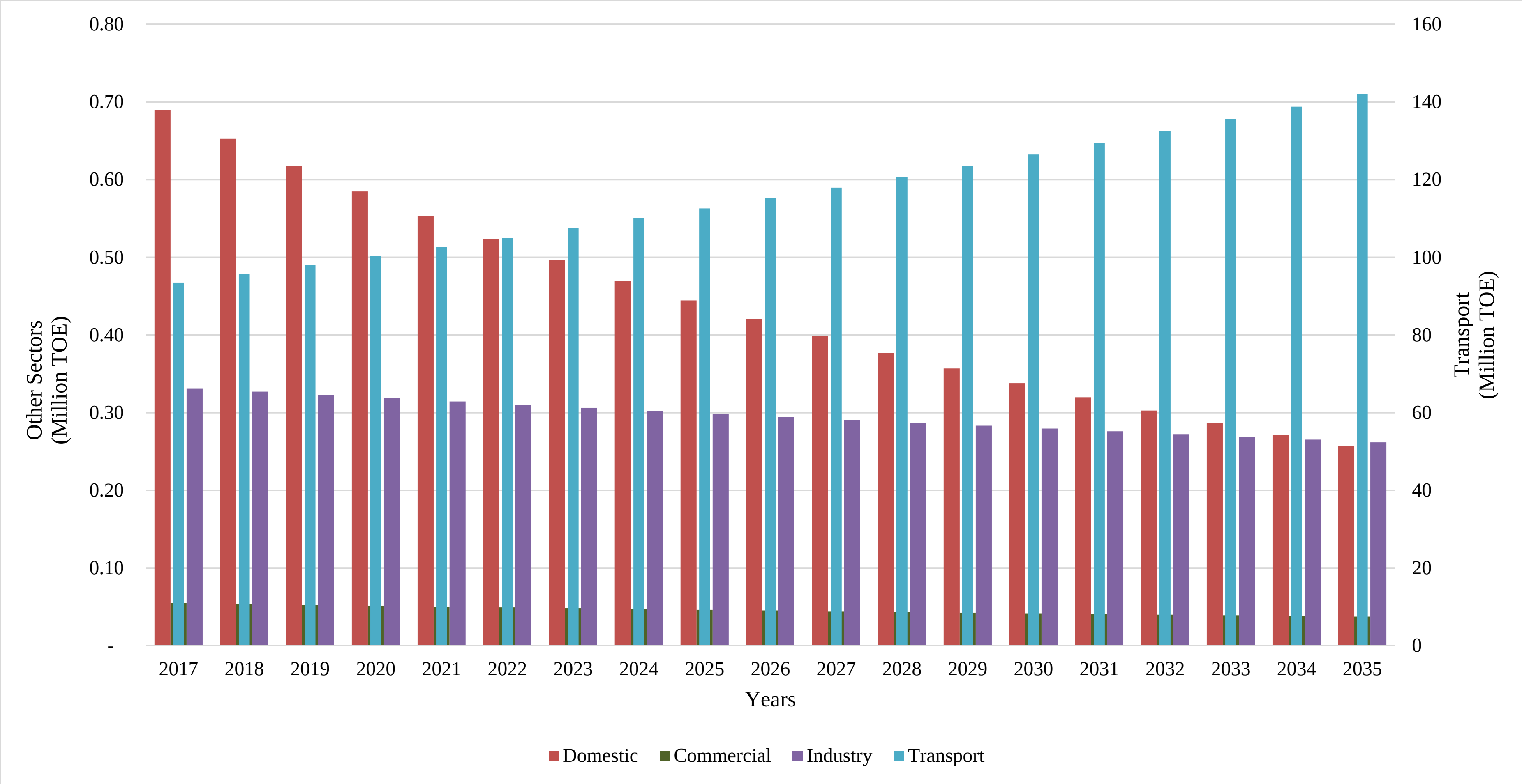


Figure 11. Estimated demand of natural gas in various sectors of consumption in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

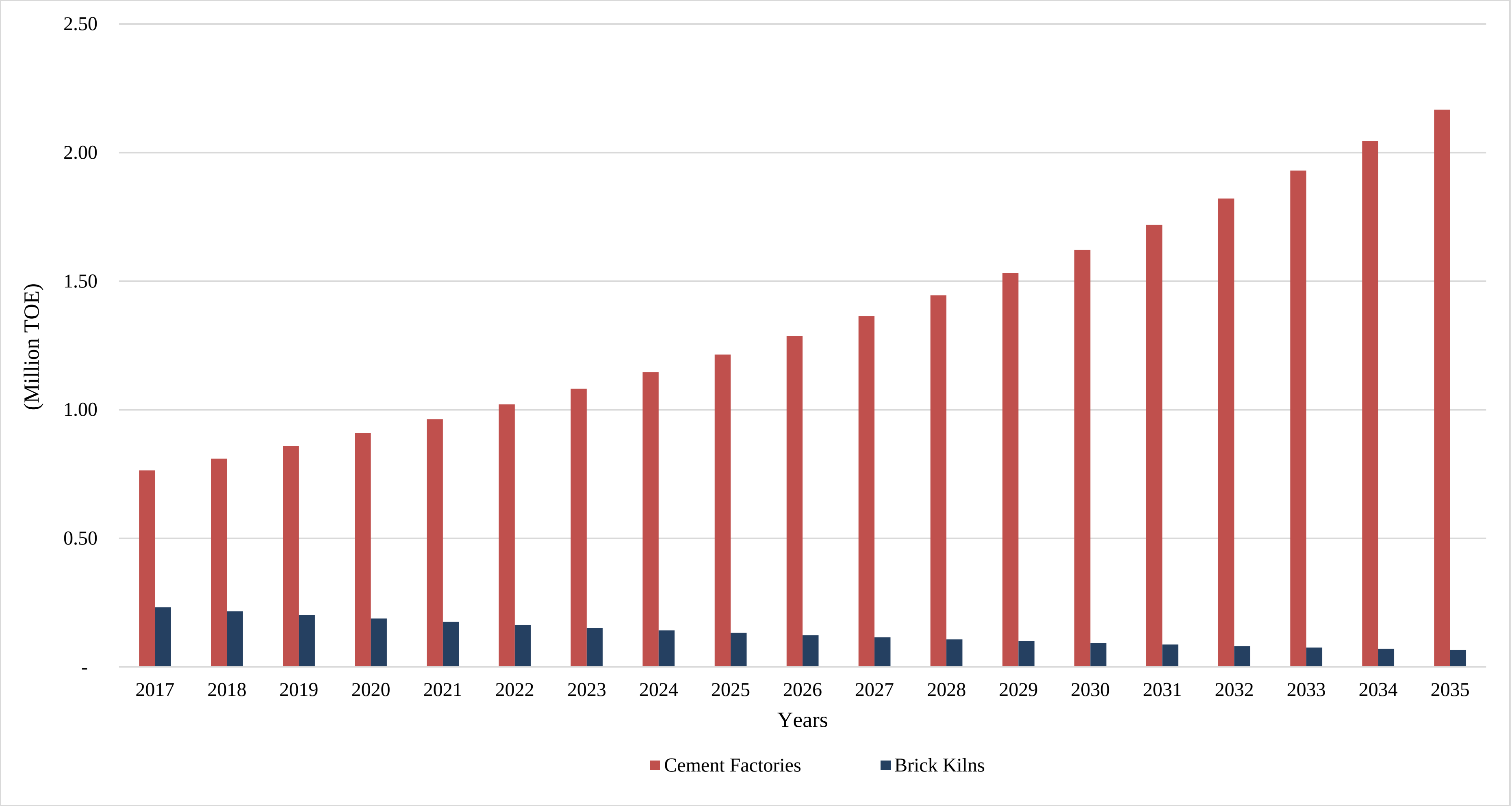


Figure 12. Estimated demand of coal in various sectors of consumption in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

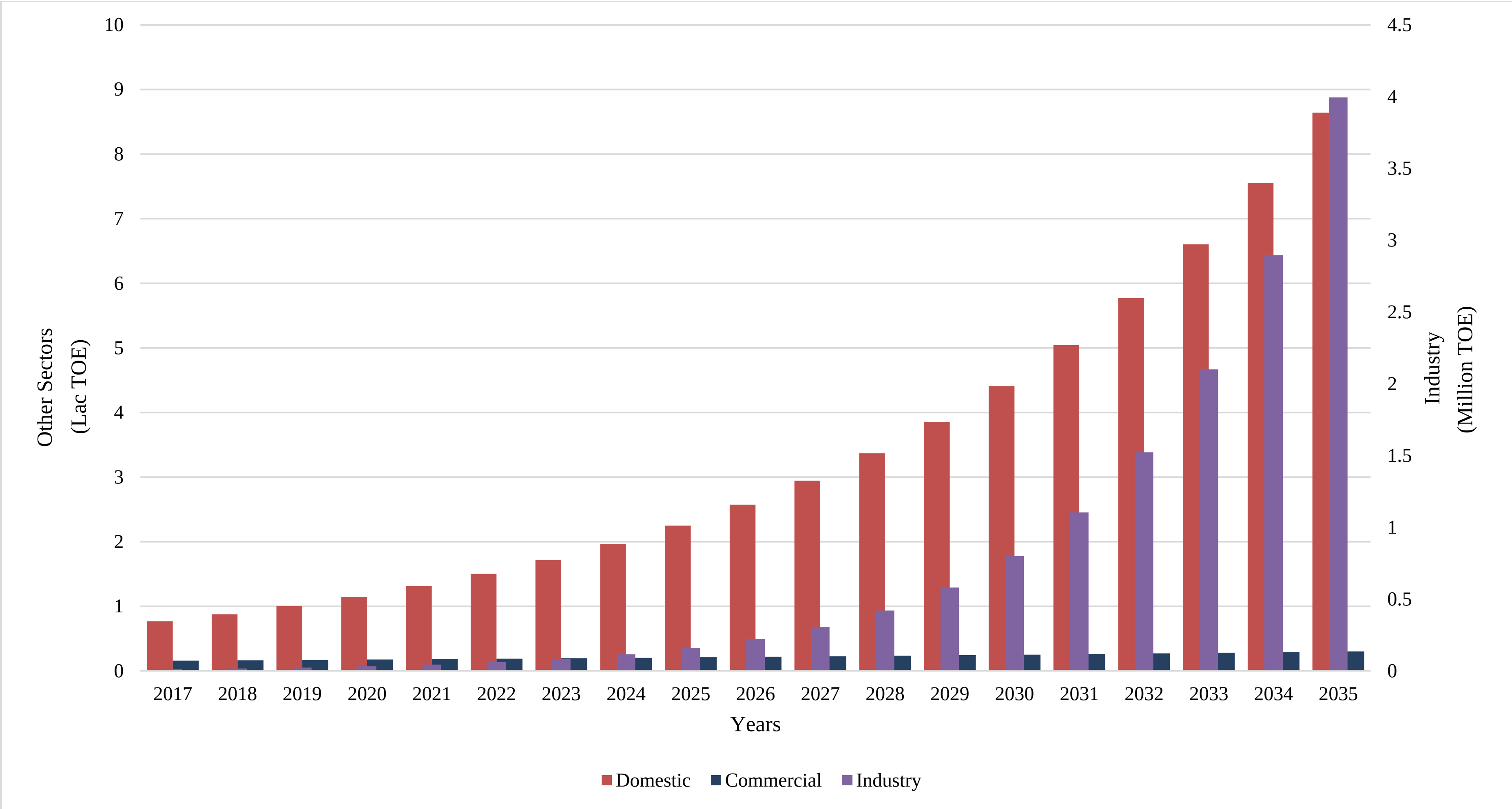


Figure 13. . Estimated demand of LPG in various sectors of consumption in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

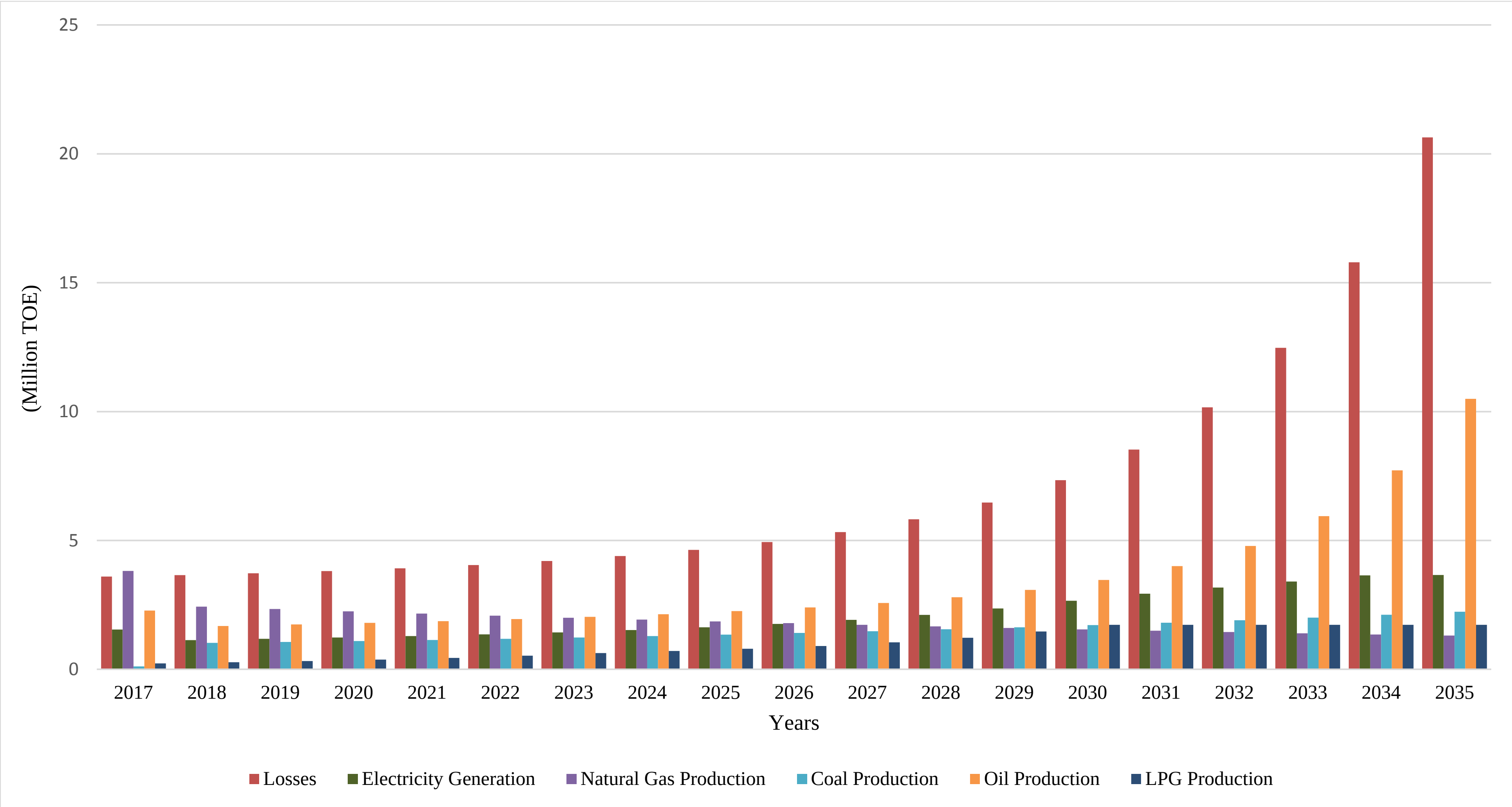


Figure 14. Required annual output of all fuels by feedstock of all fuels in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

3.1.9 Electricity Generation Analysis

The topography of KP is well suited for dam construction and there are eight rivers flowing in the region that is providing favorable environment for hydel power generation. Therefore, most of electricity generated in Khyber Pakhtunkhwa is hydel power. KP has currently thirteen power generation units having the overall capacity of 4,208 MW and historical production of 17,940 Gigawatt-hour in 2017. Glacier melting and heavy rainfall in upper regions is the main reason of the water availability for electricity generation. Khyber Pakhtunkhwa is mostly mountainous region that is a good reason for construction of dams and other storages of water with respect to cost-benefit analysis. Famous hydel power stations like Tarbela, Warsak, Duber Khwar, Allai Khwar, Malakand III PEDO and Pehur PEDO are worth mentioning (Fig. 16). Hydel power generation in KP is also contributing to fulfil the needs of other regions of the country. Many other hydropower plants are under construction to increase the electricity production to meet the daily uses of community such as Kurran Tangi Dam, Sharmai Hydropower Plant, Mohmand Dam, Suki Kinari Hydropower Plant, Dasu Dam and many others which will add to the development and prosperity of the country. Currently 1,028 micro-hydels (87.8 MW) across 21 rural districts are being developed to provide cheap renewable electricity to off-grid areas. The Micro Hydel Project (MHP) has been divided into two phases; Phase 1 (34.7 MW) and Phase 2 (53.1 MW) Government of Khyber Pakhtunkhwa have planned to take into account other resources of energy such as solar and biomass for improving the efficiency of power sector.

3.1.9 Natural Gas Production Analysis

There a huge deposits of fossil fuels in Khyber Pakhtunkhwa, natural gas occupying the central position. Natural gas is also occasionally found with crude oil reserves that is why it is found in two ways i.e. associated and non-associated. Renowned fields for non-associated natural gas production in Khyber Pakhtunkhwa are Mamikhel, Manzalai, Maramzai, Nashpha and many others. In associated form, it is found in less amount in which Makori East and Chanda are worth mentioning. The analysis of natural gas show that natural production is decreasing vigorously in both forms. It means that natural gas reserves are getting depleted uncontrolled resulting the vanishing of the resources. Associated natural gas reserves of KP is 1.6 Million Tons of Equivalent per year in 2017 and 2.94 Million Tons of Oil Equivalent per year in 2018 is a positive change. Non-associated natural gas reserves decrease from 18.18 Million Tons of Oil Equivalent per year in 2017 to 13.85 Million Tons of Oil Equivalent per year in 2018 is devastating (Fig. 17). The main reason behind this tragedy is high dependence on fossil fuels especially natural gas. It is almost used in almost every field of life building pressure in the form more extraction as compared to underground production of natural gas. The sudden decrease of natural gas supply will destructively affect the routine of life in very near future. Therefore, it is the need of the day to integrate renewable resources of energy for sustainable development as well as to avoid crisis developing in future and handle this problem effectively. However, there is a struggle to discover more and more reserves of natural gas to cope with the demand by different exploring companies.

3.1.10 Oil Production Analysis

Oil serving as a backbone in development and economics of a country, its availability is of huge importance to meet the daily needs of different sectors of its consumption.

Khyber Pakhtunkhwa is producing a large portion of crude oil of Pakistan. Oil production is increasing day by day but the reserves are being depleted enormously, which is a big threat to the stability of the development and economy of Pakistan. Oil reserves of KP is 26.6 Million Tons of Equivalent per year in 2017 and a hasty change to 21.98 Million Tons of Oil Equivalent per year in 2018 is alarming (Fig. 18). However, discoveries are also made which is balancing the equation of depletion and discover up to some extent and stabilizing the demand and supply nexus. Famous places known for the production of crude oil in KP are Nashpha, Makori East, Maramzai, Mela, Chanda and many more. As mentioned earlier the dependency on the fossil should be reduced as much as possible. Alternative energy resources should be taken into account to balance the overload on the foresaid resource. Otherwise, there will be huge disturbance in lifecycle.

3.1.11 Liquefied Petroleum Gas (LPG) Production Analysis

LPG is the by-product of crude oil and natural gas production. Nowadays it has become the most important of all resources. The main reason behind its popularity is efficiency and continuous supply for carrying out scheduled processes. As compared to other means of energy production, it is profitable with every regard. The difficulties in the supply of natural gas to the rural areas in winter is a great hurdle and cost-benefit analysis comparison of fuel oil with LPG results in recommendation of the later one. The capacity of LPG production of Khyber Pakhtunkhwa is large enough with respect to its demand but as non-renewable resource, its exhaustion will ultimately result in adversity. The increase in LPG production capacity in Gas plants from 1,100,870 Million Tons of Oil Equivalent per year in 2017 to 1,396,607 Million Tons of Oil Equivalent per year in 2018 is a good gesture. However, at the same time there is a massive decrease in crude oil plants from 401,633 Tons of Oil Equivalent per year in 2017 to 331,876 Tons of Oil Equivalent per year in 2018 is destructive (Fig. 19). The only solution to control and lessen the use of the mentioned resource is enabling the use of renewable resources such as biomass and wind energy etc.

3.1.12 Coal Production Analysis

Coal has been considered as the cheapest source of energy from ancient times. Pakistan is blessed with large number of coal reserves. In a report, Pakistan is ranked 20th by the proven coal reserves, 34th in coal production and 38th by coal consumption in the world. Pakistan imports 70% of its coal consumption. Coal exploitation is not mechanized and very slow throughout all regions in Pakistan that results in mining a very small portion of the underlying seam of coal. Coal mining in Khyber Pakhtunkhwa is done by typical methods resulting in very low production. That is why the need of province is fulfilled by imports from other provinces and abroad. Coal is mainly used in cement industry and brick kilns in KP. It is the backbone of cement industry production while a huge decrease of coal consumption is noticed in brick kilns because of shifting towards other building materials with respect to cost-benefit analysis that has pushed back the use of brick in construction. Khyber Pakhtunkhwa has coal production capacity of 469,770 Tons of Oil Equivalent per year and historical production of 112,631 in 2017 (Fig. 20). A decrease in production is being seen because of deprivation of industry from basic needs as well as less attention being paid to mechanization and modernization of the listed industry. A large amount of coal is left unmined due to old-fashioned mining techniques used. Positive steps should be taken in order to make it a compatible industry for investment to reduce the imports of the coal.

3.1.13 Greenhouse Gases Emissions Analysis

Global warming is a scientific concept that has long been debated. Global warming and climate change are caused by an increase in greenhouse gases in our atmosphere. A greenhouse gas is any gaseous substance in the atmosphere capable of absorbing infrared radiation and thereby trapping and maintaining heat in the atmosphere. The greenhouse effect, which increases the quantity of heat in the atmosphere and contributes to global warming is caused by greenhouse gases. Water vapors (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the most significant greenhouse gases, according to the Environmental Protection Agency (EPA). Agricultural practices contribute to the production of some greenhouse gases, such as methane. CO_2 is produced mostly by natural processes such as respiration and the combustion of fossil fuels such as coal, oil, gas, and LPG. Deforestation is another major source of CO_2. When trees are destroyed for producing goods or heat, the carbon that would otherwise be stored for photosynthesis is released. The degree to which a greenhouse gas influences global warming is determined by three factors: Its quantity in the atmosphere, the length of time it stays in the atmosphere, and its ability to cause global warming (GWP). The GWP is a measurement of how much energy one ton of gas will absorb over a specific period in comparison to one ton of carbon dioxide (CO_2) emissions. CO_2 has a GWP of one by definition, regardless of the time period used, because it is the reference gas. Before the industrial revolution, atmospheric CO_2 levels ranged between 180 parts per million (ppm) during ice ages and 280 ppm during interglacial warm times throughout a 20,000-year span. According to NASA's Global Climate Change portal, CO_2 levels have increased roughly 50% since the beginning of the industrial revolution in the 1750s. CO_2 levels are now exceeding 410 parts per million. The amount of greenhouse gases generated by the usage of various forms of energy resources according to Intergovernmental Panel on Climate Change Tier 1 (IPCC Tier 1) and 100-Year GWP was calculated using the LEAP model. In 2017, net greenhouse gas emissions were 243.19 million metric tons of CO2 equivalent, with 395.42 million metric tons of CO_2 predicted by 2035. Natural gas usage currently produces around 96 percent of GHGs, with 225.77 million Metric Tons of CO_2 in 2017 and an expected 340.44 million Metric Tons of CO_2 in 2035. In 2017, LPG accounted for 0.1% of total GHG emissions, or 0.32 million metric tons of CO_2 equivalent, whereas 14.98 million metric tons of CO_2 equivalent accounted for 3.8% of total GHG emissions in 2035, surpassing the amount emitted by coal consumption (Fig. 21). These emissions contribute to global warming and climate change, which has an impact on human life in some form. Many species have been endangered because of habitat disturbance. Temperature rises, harsh weather, increasing sea levels, acid rains, and a shift in the moon's early season, which has completely altered crop sowing and harvesting dates, are all major issues caused by these emissions.

3.2. Biomass Energy Scenario Analysis

3.2.1 Biomass Production Analysis

Crop biomass is a significant input in agricultural, ecological, and meteorological models, as well as one of the most important inputs in growth monitoring and yield estimation models. Estimating crop biomass accurately remains a difficult task. Remote sensing, unlike field measurement approaches, is a useful tool for assessing crop biomass on a regional or global scale (Wang et al., 2017). Biomass can be estimated using a variety of ways, but the field computation technique is the most accurate. This method has some drawbacks, such as the fact that it takes longer and requires more labor, and that it cannot be used for a broad region, thus it cannot provide us with a continuous supply of biomass. The employment of remote sensing techniques is a non-destructive strategy. We can analyze numerous characteristics that are used for biomass estimation using remote sensing. We can estimate biomass at several scales with variable temporal and spatial coverage using remote sensing (Li et al., 2015). Normalized Difference Vegetation Index (NDVI) and Dry Bare Soil Index (DBSI) for the four crops i.e. Wheat, Maize, Sugarcane and Tobacco were calculated from their boom period Sentinel-2 imagery using raster calculator in Arc Map 10.5. NDVI ranges from -1 to +1 while DBSI have a range of -2 to +2. Results showed that NDVI and DBSI range for wheat was 0.34 to 0.73 and 0.10 to 0.45, for maize 0.43 to 0.83 and 0.03 to 0.51, for sugarcane 0.40 to 0.81 and 0.02 to 0.61, and for tobacco 0.39 to 0.82 and 0.03 to 0.62 respectively (Fig. 22 & 23). Values shows that three of the four crops have high reflectance due to large canopy cover while wheat has relative lower reflectance due to small leaf area.

Area cover for each crop was calculated in Arc Map 10.5 showed that wheat is the most grown crop in the study area having area cover of 191600 hectares, 111600 hectares of maize, 86100 hectares of sugarcane and tobacco having 33600 hectares area cover (Table. 3). Wheat is grown almost everywhere in Peshawar Valley. However, a very large amount is found in Charsadda and Mardan districts. The decreased amount of crops in Peshawar and Swabi indicates that huge urbanization in Peshawar is the main reason behind the less cultivation and land reservation for tobacco crop in Swabi makes less availability for wheat. The topography of Nowshera makes its most of land unsuitable for cultivation. Maize has almost same trend of cultivation as of wheat in study area. Meanwhile, sugarcane and tobacco sowing is concentrated in specified areas such as tobacco is mostly sown in Swabi and Mardan while sugarcane is mostly is sown in Mardan and Charsadda because of its land suitability for the saying crops. The results were compared with ground data of area cover showed over estimation of 4.35% for wheat, 9.8% for maize, 3.6% for sugarcane, and 17.5% for tobacco crop respectively. The increased estimation of biomass for each crop was due to the presence of other vegetation in the study area. Exceptional over estimation was noticed in tobacco area because of the vegetables and fodder being grown in the fields after the harvesting of wheat. Bare soil area was also calculated during maturity season of each crop and result indicated that there was the least bare soil in during peak period of wheat crop estimated 643 sq.km, which is enforcing the fact that wheat is the most grown crop in Peshawar Valley. Bare Soil for maize and sugarcane crops are 1547 sq.km and 1580 sq.km respectively showing the importance of growing these crops. However, there is a large area of bare during tobacco crop season because almost all of the vegetation has been harvested exposing large bare surface. Leaf Area Index (LAI) was calculated using derived NDVI for the wheat and maize crops for calculating their biomass. The derived value of LAI for wheat is 4.37 and 5.01 for maize (Fig. 24). The difference between values is due to large leaf area of maize as compared to wheat. Fresh biomass of wheat and maize crops was calculated using the formula mentioned in methodology that showed that the one hectare of wheat crop contains 11.08 tons of fresh biomass. Similarly, one hectare of maize crop carry about 24.12 tons of fresh biomass. The difference in the biomass of the mentioned crop is due to the height, leaf area and stem diameter. Estimated area under cover for wheat crop is 191,600 hectares resulting in 2,123,886 tons and 111,600 hectares of maize crops produced 2,691,792 tons of fresh biomass. Dry mass was obtained in the form of biomass of pods, cobs and stalks using production of wheat and maize crops. Results indicated that 398,302 tons of wheat crop produced 119,491 tons of pods and 597,453 tons of stalks while 254,343 tons of maize produced 76,303 tons of cobs and 508,686 tons of stalks. Similarly, dry biomass of sugarcane and tobacco crops calculated as per methodology showed that biomass per plant of sugarcane is about 1.22 kilograms and there are about 131 plants in 100 meters continuous row with spacing of 2.5 feet resulting in the production of 3.563 tons per hectare. Dry mass of single tobacco plant is 0.36 kilograms and there are about 105 plants in continuous 100 meters row with spacing of 3 feet resulting in the production of 1.26 tons per hectares. The calculated area cover of sugarcane is 86,100 hectares, which produces about 306,774.3 tons of bagasse while tobacco area cover was 33,600 hectares resulting in production of 42,336 Tons of biomass. Total amount of biomass produced from the four crops in the area of interest is equal to 1,651,043.3 tons while 4,946,716.6 tons is the potential production in Khyber Pakhtunkhwa. The major contribution in this digit is of wheat and maize that combine share 78.8% in the total biomass production.

3.2.2 Biomass Energy Estimation

Renewable energy sources are becoming increasingly important if we are to make the necessary reforms to mitigate global warming effects. Biomass is the most popular source of renewable energy, widely employed in the developing world but less so in the developed world until recently (McKendry, 2002). Direct combustion of biomass for the generation of thermal energy has been practised since ancient times. Advanced biomass conversion technologies, on the other hand, are utilized to efficiently utilize biomass for energy and convert it to acceptable forms of fuel. Biomethanation, gasification, and biomass-to-liquid-fuel conversion are the main technical approaches for biomass conversion. The biomethanation of cattle dung is well-known, but liquid fuel is obtained by extracting non-edible oil from plants. Between 78 and 82 percent of the energy in biomass is captured during the gasification process. A kilogram of dry biomass yields approximately 2.6m^3. The calorific value of one kilogram of gas is 4.5 to 5 MJ/m^3, and the stoichiometric air-to-fuel ratio is 1.3 of producing gas. Taking into consideration the biomass produced in study area indicates that it can produce 4,292,711,800m^3 of gas that is equal to 487,016 TOE by taking the average calorific value of 4.75 MJ/m^3 that is increasing 1.34% annually. The capability of Khyber Pakhtunkhwa to produce gas is 12,905,652,760m^3 that is corresponding to 1,464,169.5 TOE by taking the average calorific value of 4.75 MJ/m^3 that is decreasing by 0.17%. The supposition of converting all the biogas produced from the biomass in the study area to electricity leads to the addition of 1959 MW in the existing electricity generation capacity. However, as most of biomass is used as a fodder for animals and other purposes also therefore 25% of the total biomass produced is considered available for biomass energy production (Fig. 25). However if extended throughout the province will sufficiently decrease the dependency on the fossil fuels which in reward will give a human friendly environment. The increase in biomass production in the area of interest is due to the advanced and mechanized technology usage in the farming while the overall biomass capacity of Khyber Pakhtunkhwa is going to decrease due to rapid increase in urban sprawl. The use of all other accessible fuel energy sources is necessary for the reduction of imported forms of energy and the conservation of the limited supply of fossil fuel. Biomass is a renewable energy source that can be used in place of fossil fuels. Biomass is the third most abundant energy source after oil and coal due to its abundance.

3.2.3 Greenhouse gases Emissions from Biomass Energy

The scientific concept of global warming is well established. Global warming and climate change are caused by increased greenhouse gas levels in our atmosphere. A greenhouse gas is any gaseous substance in the atmosphere that may absorb infrared radiation, hence trap, and retain heat. The greenhouse effect, which increases the heat in the atmosphere and contributes to global warming, is caused by greenhouse gases. According to the Environmental Protection Agency (EPA), the most significant greenhouse gases are water vapors (H_2O), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (CH_4). Agricultural methods produce some greenhouse gases, such as methane. CO_2 is mostly produced by natural processes such as respiration and the combustion of fossil fuels such as coal, oil, gas, and LPG. Deforestation is a major source of CO_2. When trees are cut down to, make goods or generate heat, the carbon that would otherwise be stored for photosynthesis is released. Three factors influence how much a greenhouse gas contributes to global warming: Its quantity in the atmosphere, the length of time it stays in the atmosphere and its potential for global warming (GWP). The GWP is a measurement of how much energy a ton of gas will absorb over a particular period compared to a ton of carbon dioxide emissions (CO_2). Because CO_2 is the reference gas, it has a GWP of one no matter what time period is selected. CO_2 levels in the atmosphere ranged between 180 parts per million (ppm) during ice ages and 280 ppm during interglacial warm times throughout the 20,000-year period preceding the industrial revolution. According to NASA's Global Climate Change webpage, CO_2 levels have increased roughly 50 percent since the beginning of the industrial revolution in the 1750s. CO_2 levels have risen to more over 410 parts per million (ppm) today. The LEAP model's analysis of the amount of greenhouse gases emitted from the usage of various forms of energy resources according to IPCC Tier 1 and 100-Year GWP revealed that net greenhouse gas emissions are rapidly growing. GHG emissions are also produced during the production of power from biogas, with output expected to be 28.82 thousand Metric Tons of CO_2 Equivalent in 2017 and 116.71 thousand Metric Tons of CO2 in 2035, according to the estimation results (Fig. 26). However, when compared to other sources of energy, life assessment cycle analysis using software such as SimaPro and GaBi demonstrates that net GHG emissions are either compensated or very low. These emissions enforce to global warming and climate change, which has an impact on human life in some form. Many species have been endangered because of these disturbances to their habitat. Temperature rises, harsh weather, increasing sea levels, acid rains, and the changing of the moon's early season, which has completely altered crop sowing and harvesting periods, are all difficulties caused by these emissions.

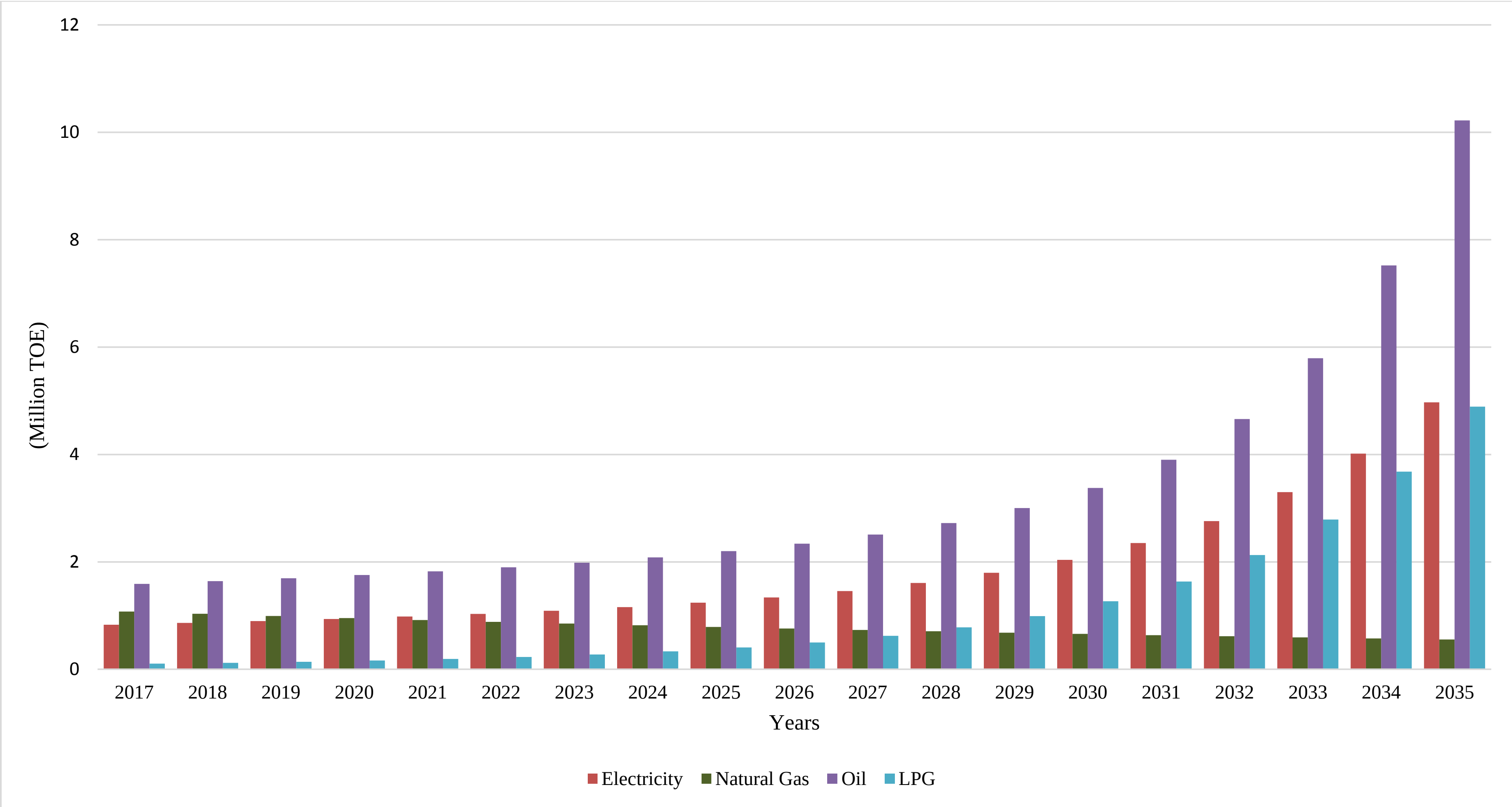


Figure 15. Annual losses by transmission and distribution of all fuels in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

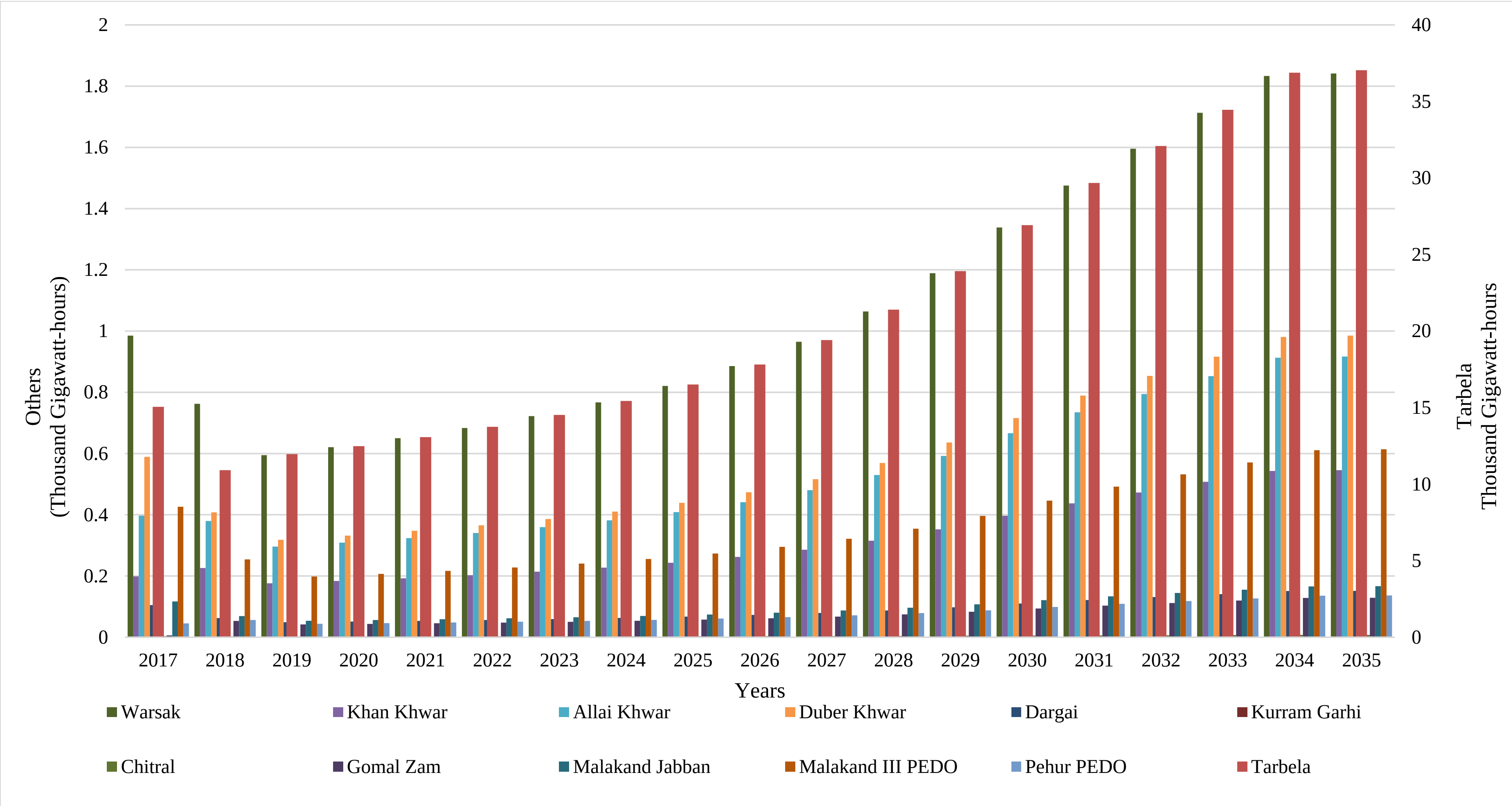


Figure 16. Required annual output of electricity by all hydropower plants in gigawatt-hours in Khyber Pakhtunkhwa (Reference Scenario).

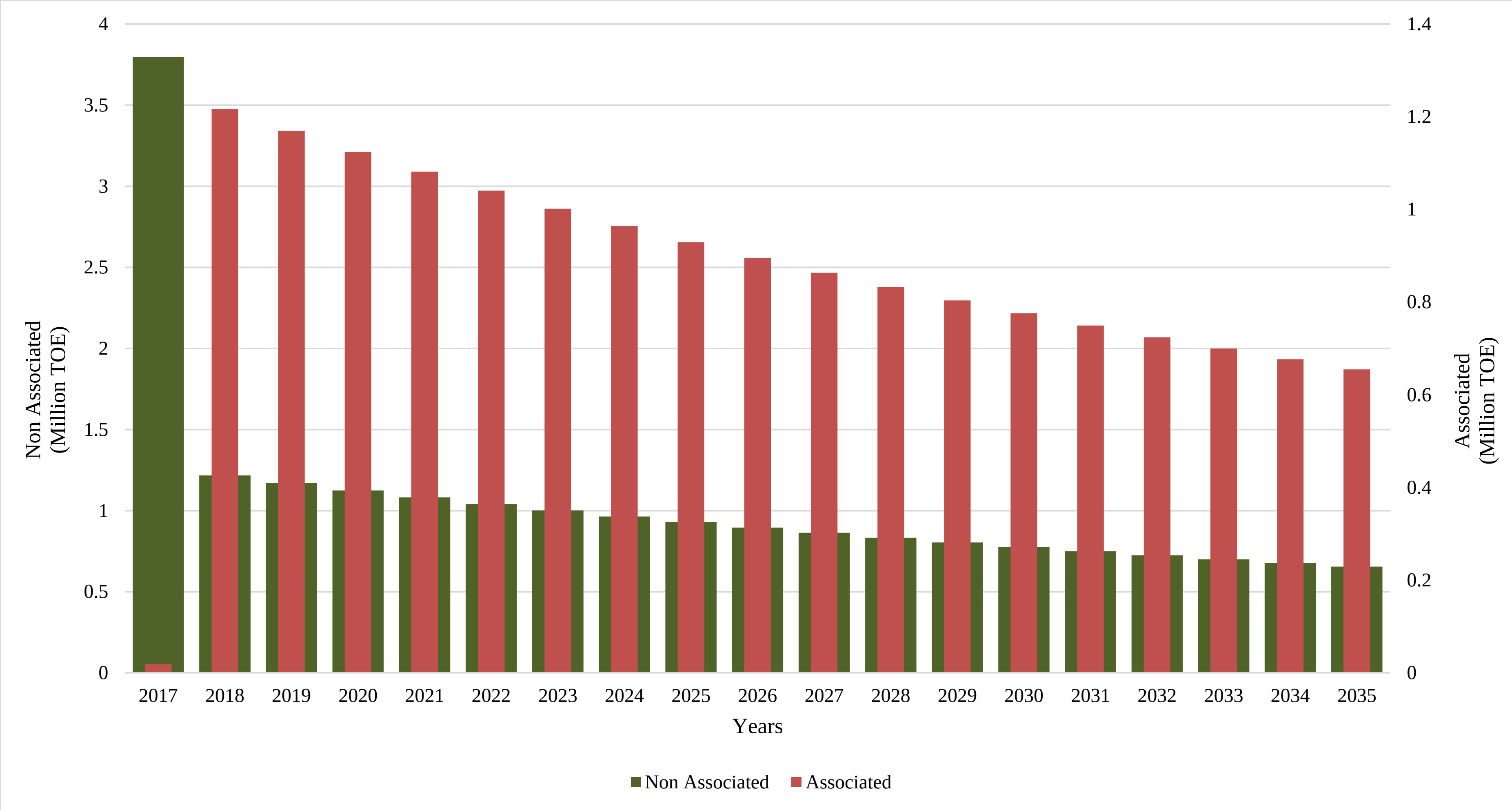


Figure 17. Required annual output of natural gas by feedstock of all wells in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

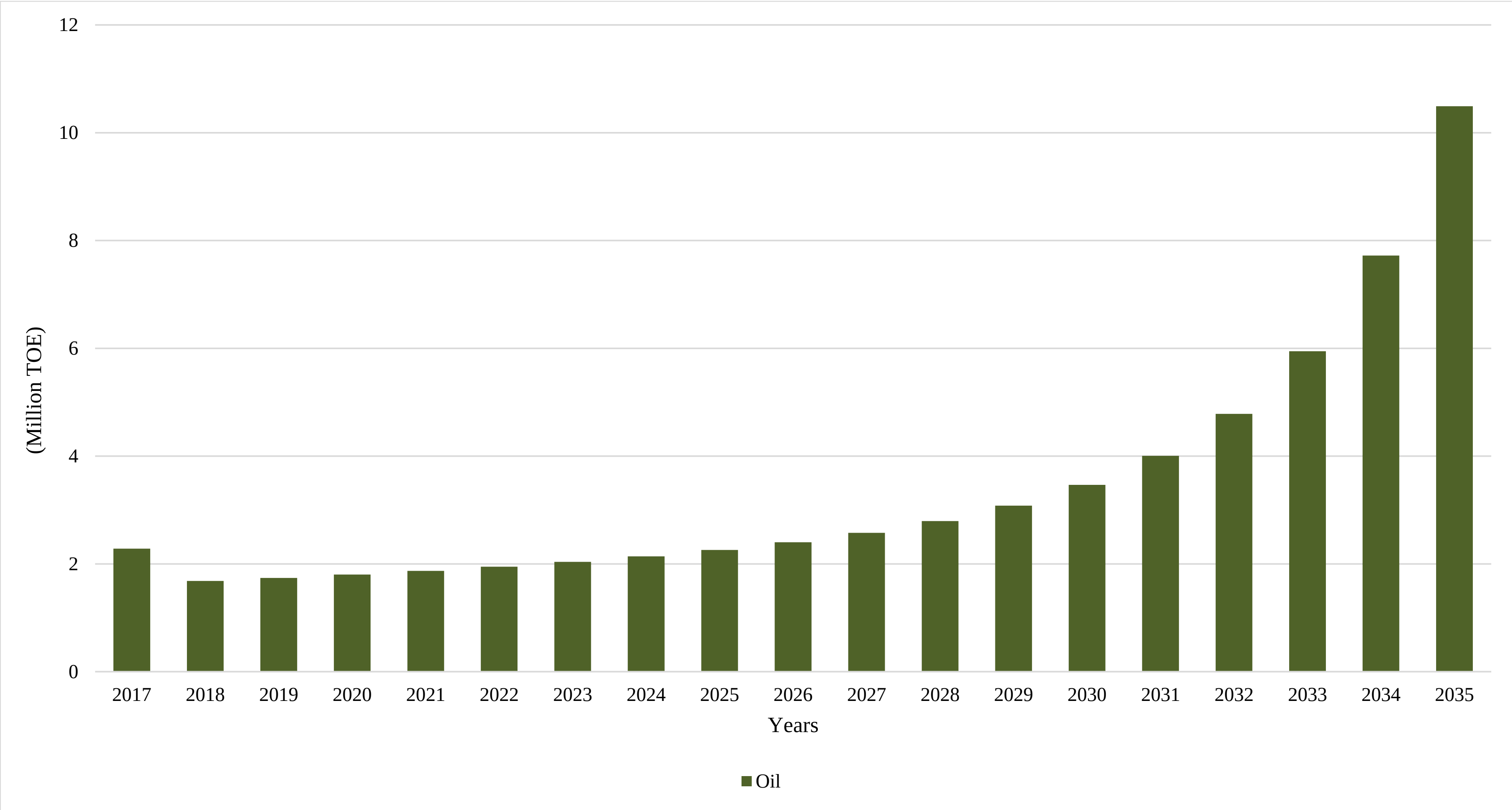


Figure 18. Required annual output of fuel oil by feedstock of all wells in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

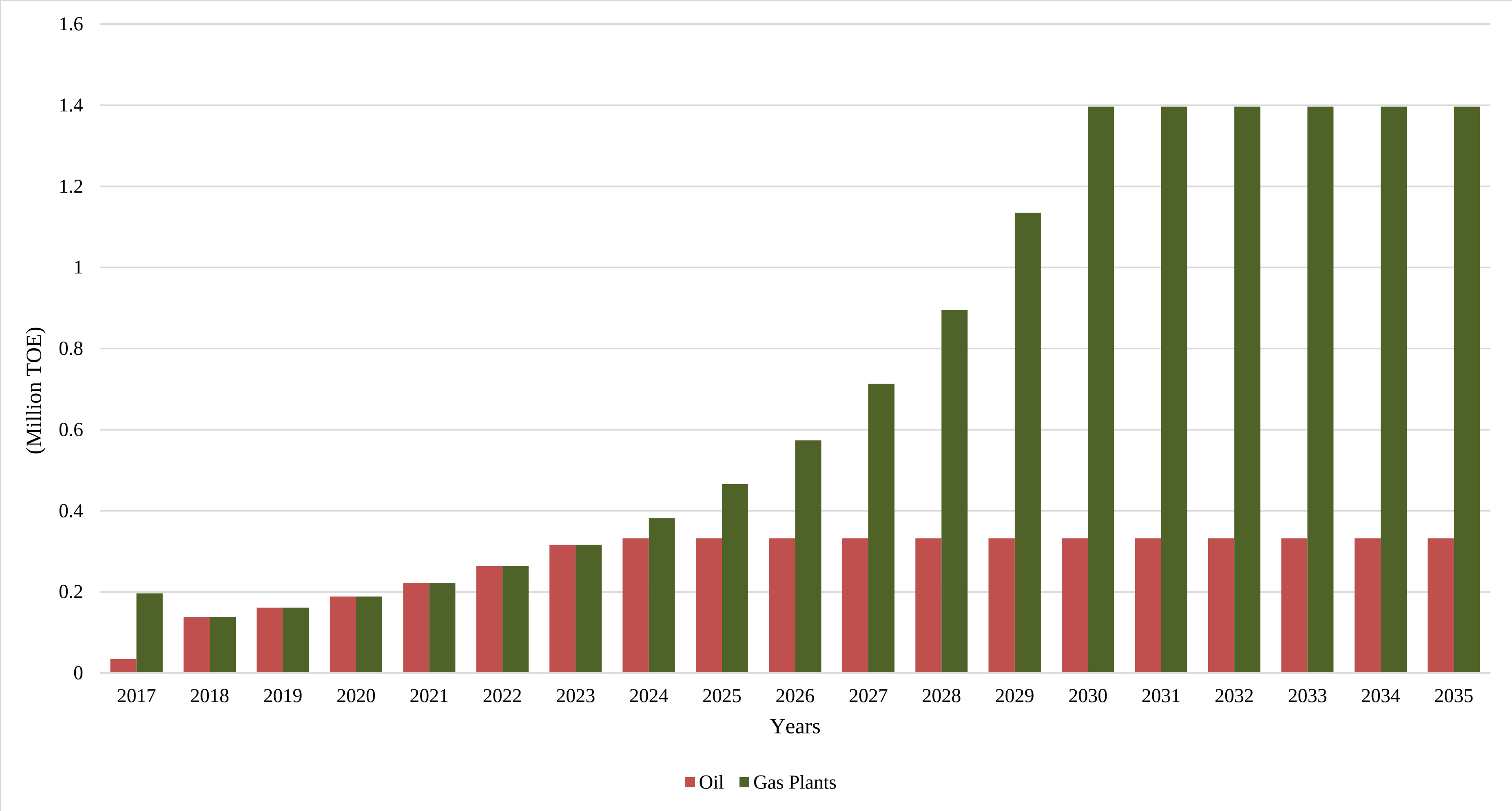


Figure 19. Required annual output of LPG by feedstock of all sources in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

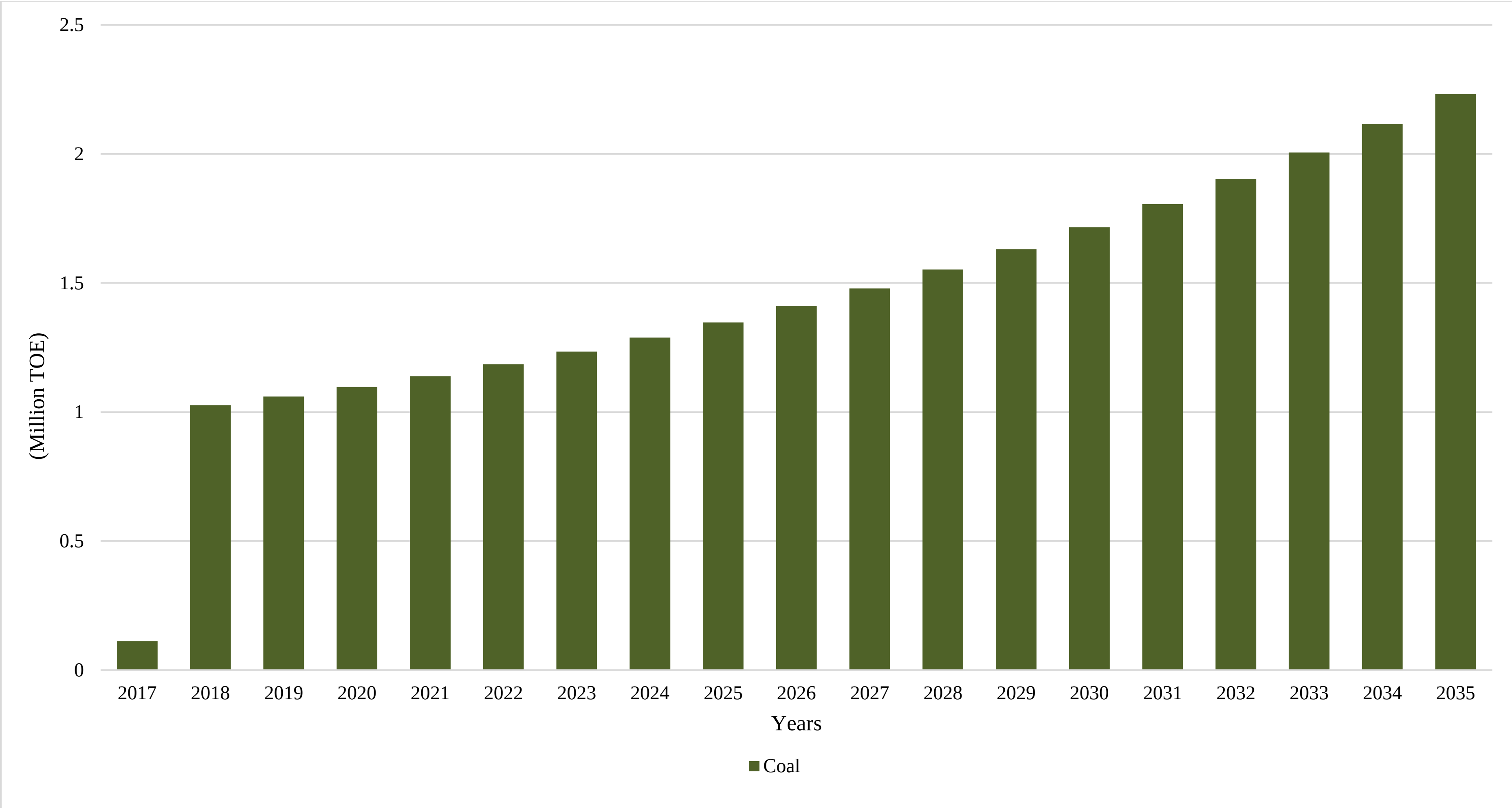


Figure 20. Required annual output of coal by feedstock in Tons of Oil Equivalent (TOE) in Khyber Pakhtunkhwa.

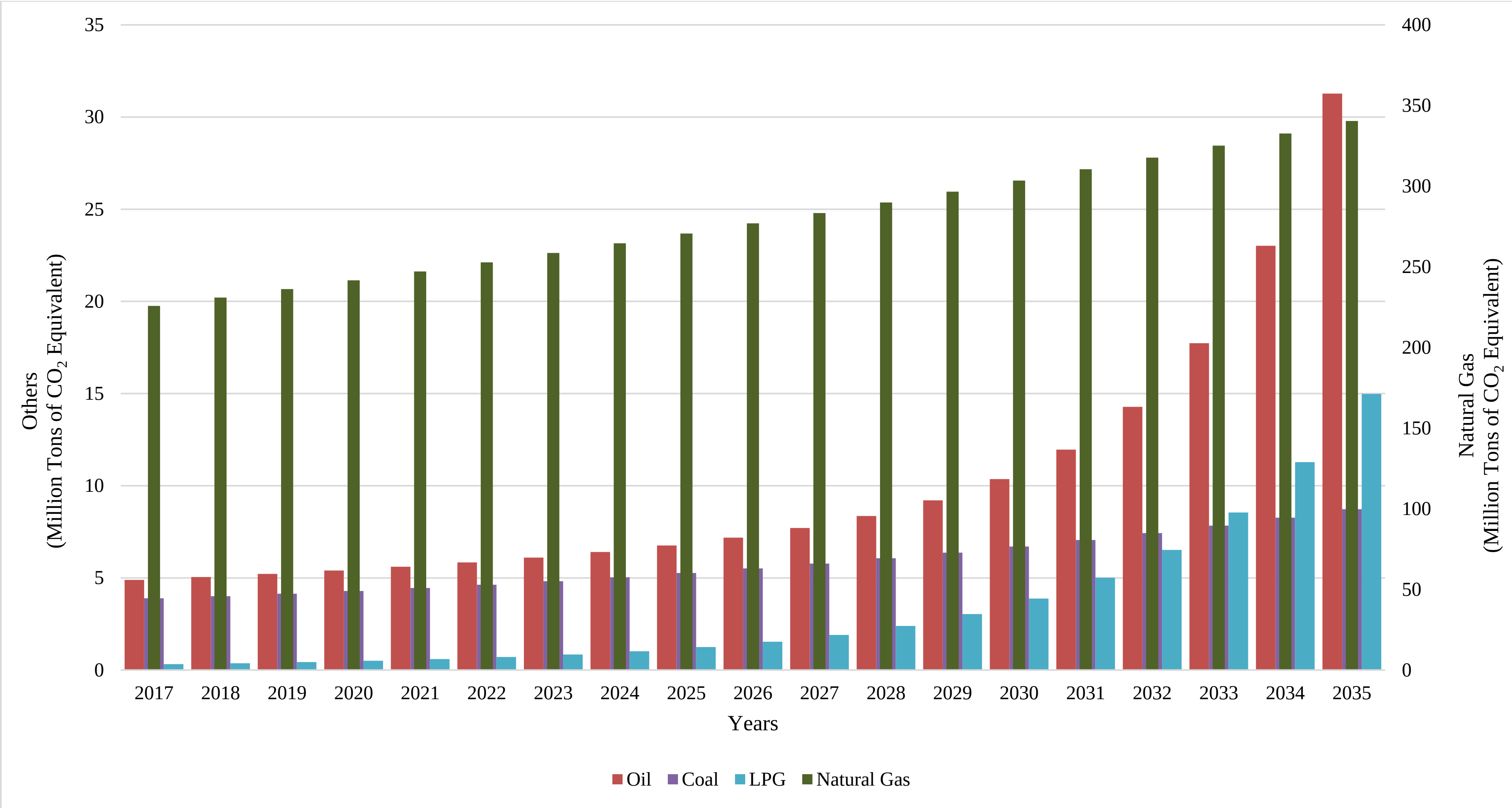


Figure 21. 100-years Global Warming Potential (GWP) of all fuels in tons of CO_2 equivalent in Khyber Pakhtunkhwa (Reference Scenario).

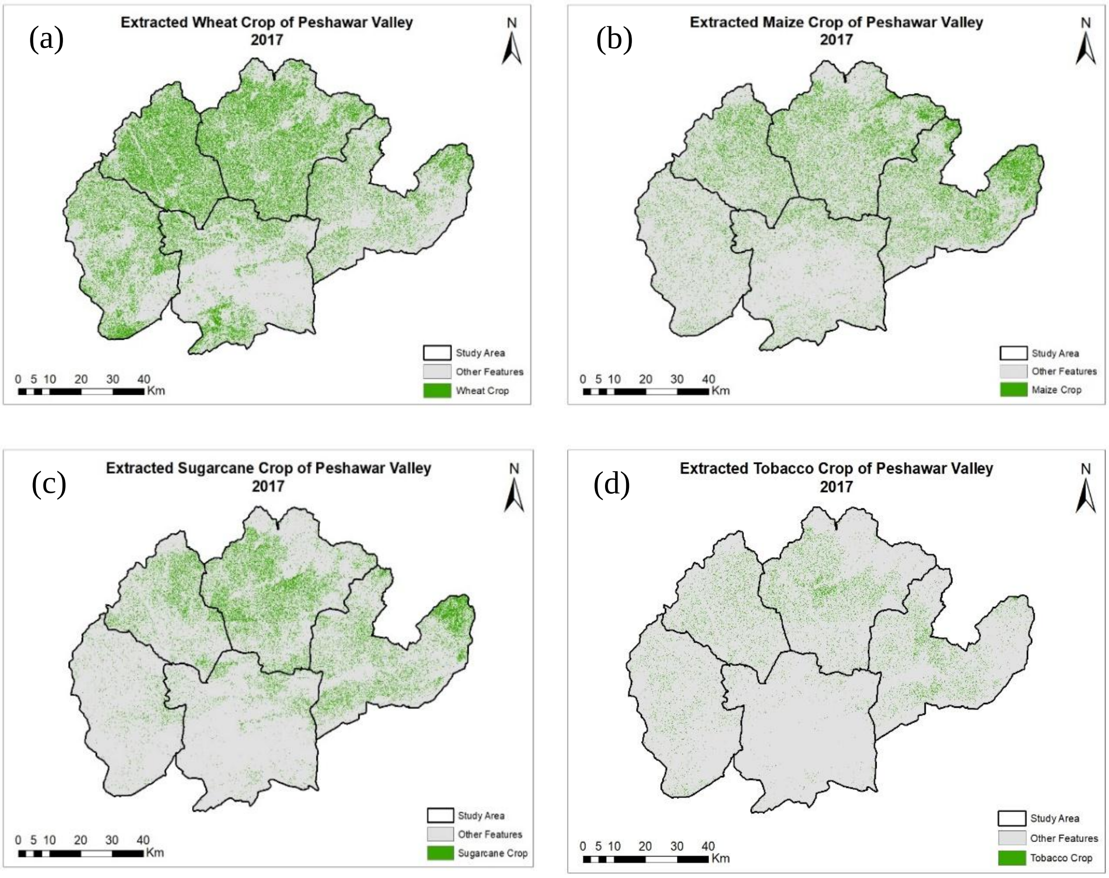


Figure 22. Vegetated area covered by (a) wheat (b) maize c) sugarcane and (d) tobacco crops.

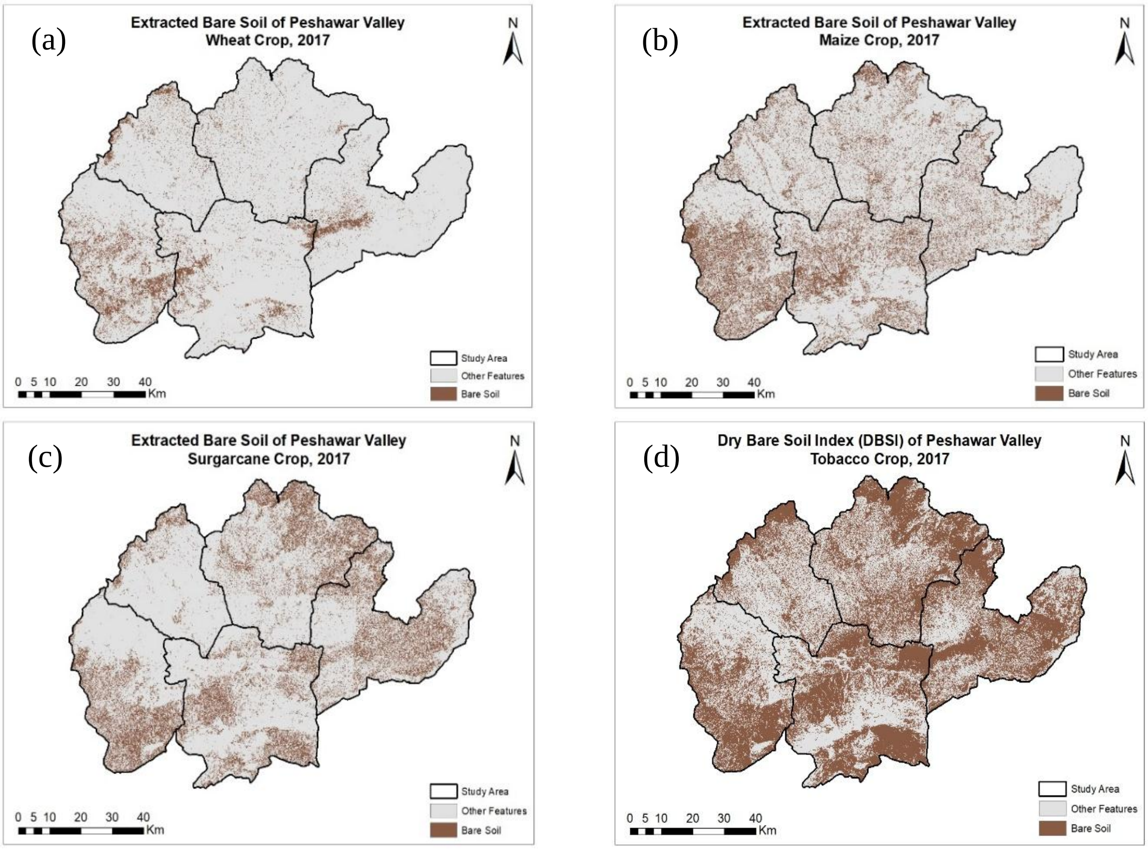
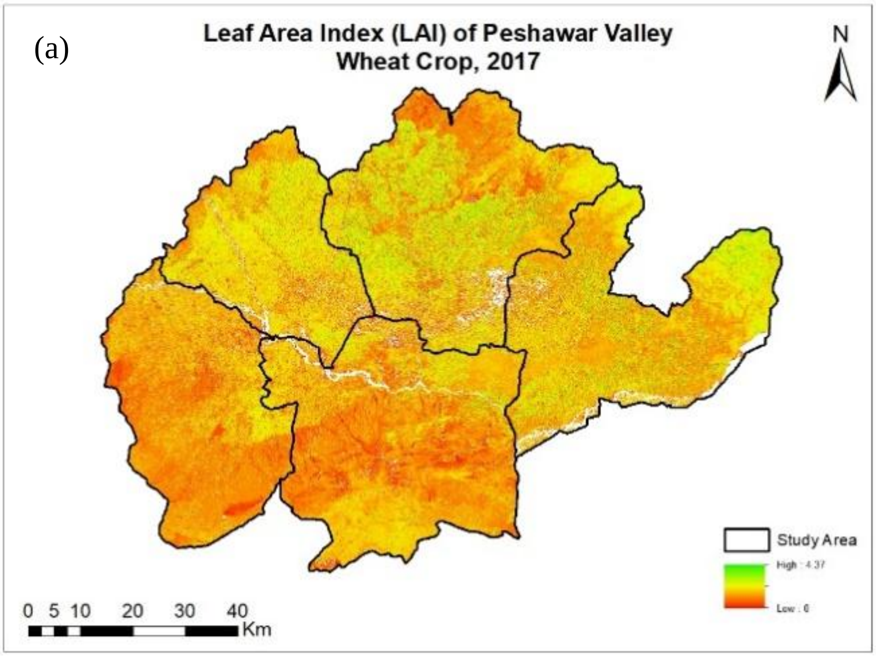


Figure 23. Bare soil during the peak season of (a) wheat (b) maize (c) sugarcane and (d) tobacco crops.



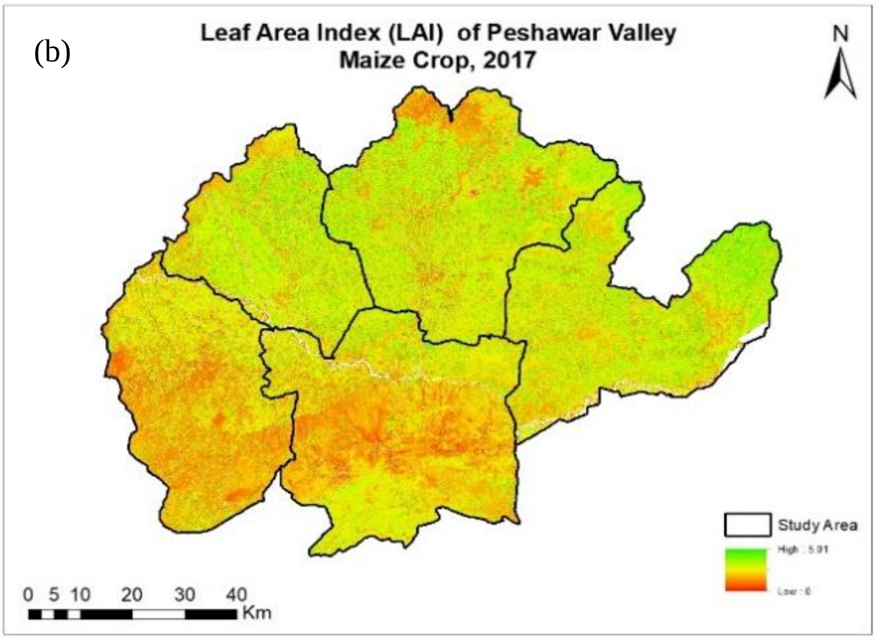


Figure 24. Leaf Area Index of (a) wheat and (b) maize crops.

Table 3. Area cover statistics and indices ranges of crops.

S. No.	Crop	Estimated Area (ha)	Actual Area (ha)	Difference (%age)	NDVI Range (+1 --- -1)	Estimated Bare Area (ha)	DBSI Range (+2 --- -2)
1	Wheat	191,600	183,617	4.35	0.34 --- 0.73	64,300	0.10 --- 0.45
2	Maize	111,600	101,619	9.8	0.39 --- 0.82	154,700	0.03 --- 0.62
3	Sugarcane	86,100	82,717	3.6	0.40 --- 0.81	158,000	0.02 --- 0.61
4	Tobacco	33,600	28,600	17.5	0.43 --- 0.83	373,800	0.03 --- 0.51

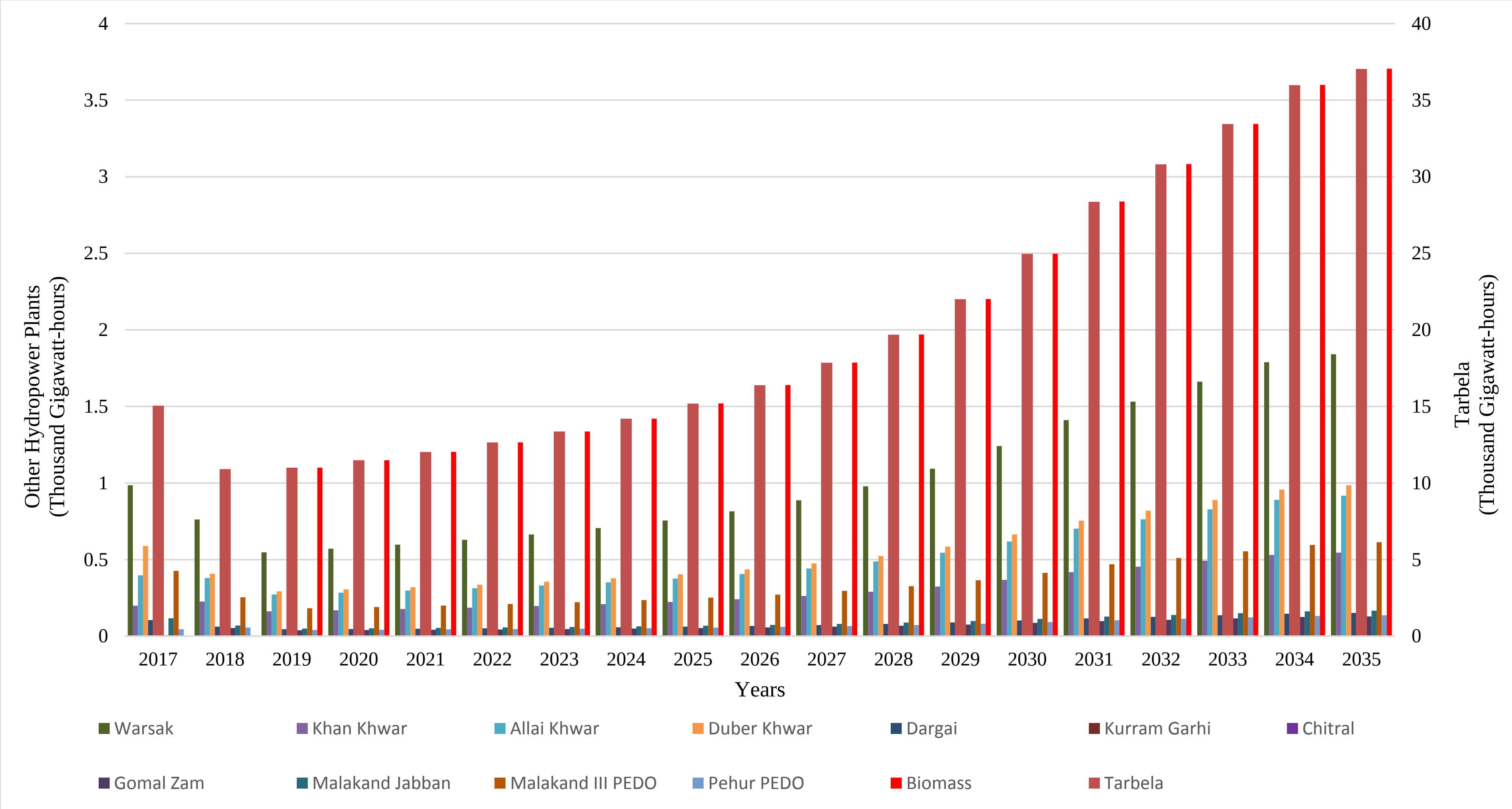


Figure 25. Required annual output of electricity by all hydropower plants in Gigawatt-hours in Khyber Pakhtunkhwa (Biomass Scenario).

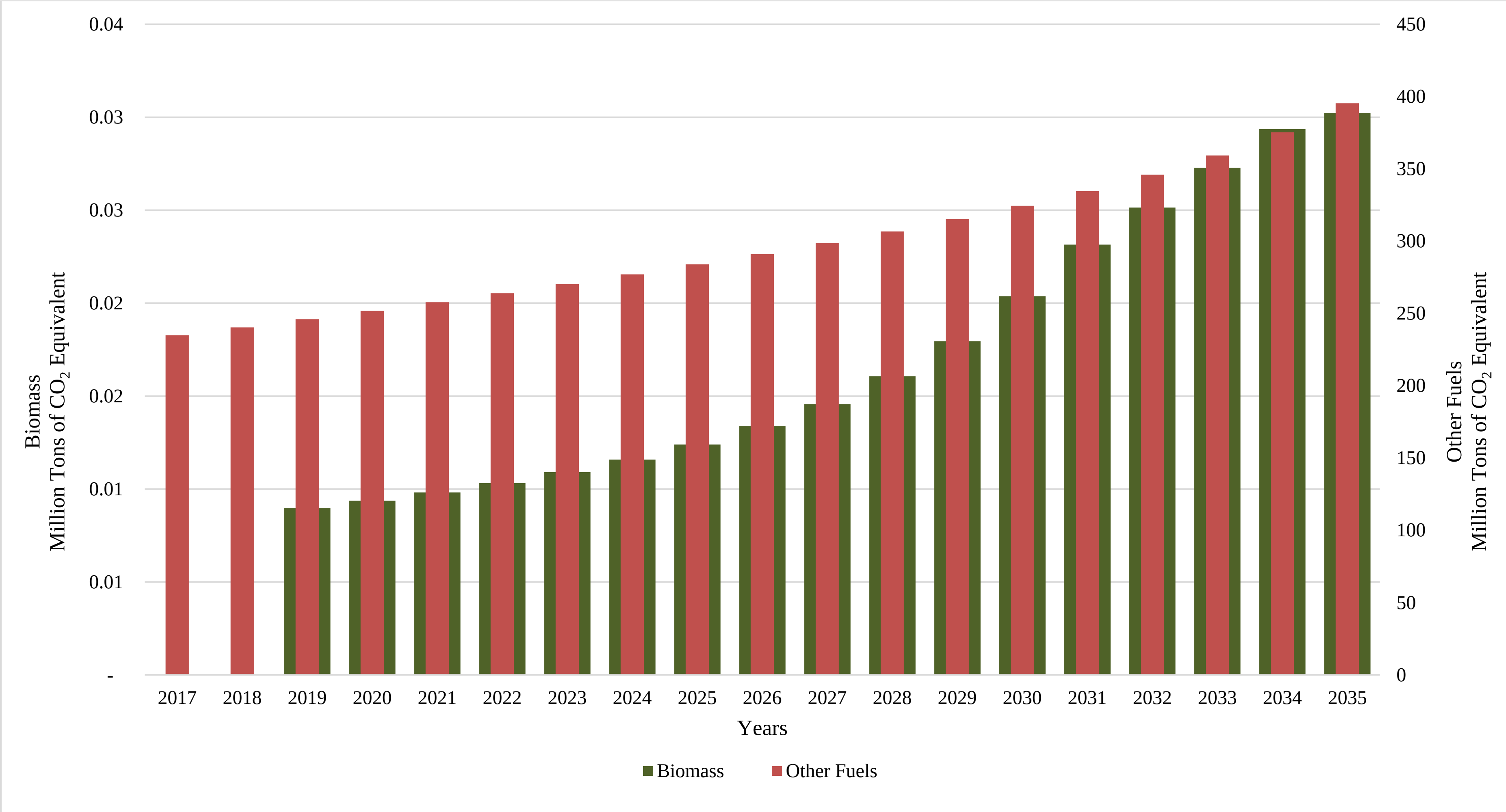


Figure 26. Comparison of 100-years Global Warming Potential (GWP) in tons of CO_2 equivalent of both Scenarios in Khyber Pakhtunkhwa.

Chapter 4

CONCLUSTION AND RECOMMENDATIONS

4.1 Conclusions

The energy sector is critical to a country's development, particularly in terms of economic development. A major problem is meeting the growing demand for energy in a safe and environmentally appropriate manner. Any blockage in the availability of energy sources to a country's development and economy is referred to as an energy crisis. The increase in population and development has resulted in a rise in worldwide energy demand. Together, oil, coal, and natural gas produce 85 percent of the world's energy. Oil will last 42 years, natural gas 61 years, and coal 133 years at current production rates. According to an overview of the energy scenario, Pakistan is an energy-deficient country. Electric power capacity is now around 17,000 MW, with peak demand around 22,000 MW and an average shortfall of around 5,000 MW. Pakistan spends more than 60% of its foreign currency on fossil fuel imports. Energy shortages have cost the economy up to 4% of GDP during the last few years. The LEAP model was used to examine and forecast current demand for various types of energy sources, such as electricity, natural gas, fuel oil, coal, and LPG, in various sectors of consumption, including residential, commercial, industrial, and transportation. According to the findings, total demand from all sources is around 98.10 million Tons of Oil Equivalent (TOE), and it is growing at an alarming rate of 2.93 percent each year. The demand for most energy sources, such as electricity, fuel oil, coal, and LPG, is rapidly expanding, while demand for natural gas is declining in all sectors except transportation, which is its primary consumption source. The exponential expansion in population, as well as the industrialization and modernization of lifestyles that are paving the way to make human existence easier, are driving up demand. Excessive exploitation of fossil fuels is occurring to meet the energy demand in order to maintain the way of life. Furthermore, there will be an unanticipated increase in energy consumption in the near future, putting additional strain on fossil fuel stocks. The increasing rate of resource exploitation will result in a scarcity of these reserves to meet the basic demands of future generations leading to chaos and, as a result, world instability. Global warming is a well-established scientific concept. Global warming and climate change are caused by increased greenhouse gas levels in our atmosphere. The most significant sources of GHG emissions are fossil fuels. With an annual rise of 2.94%, current energy use produces around 240.35 million tons of CO_2 equivalent at the 100-year Global Warming Potential (GWP). Due to the growing demand, energy output must be increased, resulting in a dramatic increase in the depletion of fossil fuels. Devastating depletion and use of fossil fuels is endangering the habitats of many animals and jeopardizing the natural environment's balance. Renewable energy sources such as wind, sunlight, water, and biomass should be used to avoid climatic threats and fossil fuel shortages in the future. If we are to implement the required reforms to limit the effects of global warming, renewable energy sources are becoming increasingly vital. Biomass is the most extensively used renewable energy source in the developing world, although it has been less widely used in the industrialized world until recently. Biomass is one of the best renewable energy sources that can be used to meet energy demand while also contributing to the reduction of pollutants in the environment. The biomass of the four crops (Wheat, Maize, Sugarcane, and Tobacco) was estimated using spectral indices such as NDVI and biophysical features of the crops such as; height, stem thickness, and LAI yielding a total of 1,651,043 tons, and DBSI was used to identify bare land during the boom green period of each crop in the study area. Estimation of biomass energy showed that 25% of the total biomass in the research region could produce about 489 MW of electricity, which could have a significant influence on fulfilling energy demand while also avoiding the pollution produced by using fossil fuels to produce the same amount of energy.

4.2 Recommendations for further Research

In terms of height determination helped by ground survey data, combining LiDAR sensor data with other passive remote sensing datasets can improve the accuracy of biomass estimation. Because of the great spectral and spatial resolution, drone data can help distinguish between different types of vegetation, which helps improve classification results. When various vegetation indices are compared, it can help identify certain types of vegetation and improve accuracy.

Sustainable development necessitates the transition from fossil fuels to renewable energy technologies such as biomass, solar, and wind energy through sophisticated experimentation. These renewable energy resources must be investigated in a practical way in order to reduce the use of fossil fuels in energy production while maintaining environmental balance. Municipal waste and animal manure may both be used to generate sustainable energy. Biomass for energy needs to be introduced to society through improved study in order to make use most of its potential energy.

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