Energy Demand Projection and Economy Nexus of Pakistan

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Abstract

In the fundamental study to design sustainable electricity generation, long-term electricity demand forecasting has taken on a crucial role. The Low Emissions Analysis Platform (LEAP®) software is used in this study to estimate the demand for energy by various consumer groups including commercial, residential, agricultural, and industrial for the study period (2023-2050). The electricity demand is forecasted under different Gross Domestic Product (GDP) growth scenarios. The developed scenarios are reference, low economic growth, medium economic growth, and high economic growth scenarios. This study identifies the key relationship between energy demand and the economy of Pakistan. It is found that energy demand and the GDP of the country have a direct relationship as one quantity increases, the other one also increases, and vice versa. 3.56% growth rate of GDP under the low GDP growth scenario causes an increment in energy demand from 137.97 million MWh in 2023 to 374.79 million MWh. Medium and high GDP growth scenario pertains to GDP growth rates of 5.79% and 10.22% which causes an increment in energy demand to 652.17 million MWh and 1,244.75 million MWh by 2050. The results of this study are significant and provide insight into electricity demand growth under the economic scenarios that could be useful for sustainable electricity planning in Pakistan.

Keywords—Energy demand, economy, gross domestic product, sustainability, Pakistan

1 Introduction

PAKISTAN's electricity consumption and power outage continue to increase as the population grows [1]. Electricity infrastructure planning is linked to electricity demand and gross domestic product (GDP), especially in developing countries such as Pakistan [2]. Pakistan plays a one-way causal role in demonstrating that electricity demand is increasing with higher economic growth [3]. Pakistan has an exceptional increase in electricity demand due to a stable annual GDP growth rate of 6% from 2002 to 2007 lack of adequate infrastructure planning in the country caused a major power outage in 2010, it lost 2.5% of GDP, unemployed 535 million industrial workers and lost $ 1.3 billion in exports [3]. Energy economics is the descriptive analysis of the distribution of resources to provide energy to the population. Excessive reliance on energy market policies, and supply and demand responses, is a major source of uncertainty for energy planners primarily focused on creating the conditions for energy capital investment [4], [5].

Electricity consumption in Pakistan can be divided into five levels: household, industrial, commercial, agricultural, and other [6]. Each sector of the economy shows a typical increasing trend in electricity demand [7]. Pakistan's electricity demand outstrips supply, exacerbating power shortages [7], [8]. The share of domestic consumption increased rapidly from 33% to 49.2% during 1991- 2016 and commercial sectors also slightly increased [9]. While the industrial sector decreased from 35.23% to 27.7% and also agriculture decreased from 17.8% to 9.4% [9]. Researchers have conducted extensive research on Pakistan's energy system using modeling tools, but this study only considers research on electricity demand forecasting for national-level energy programs as per the economical growth

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using the Low Emissions Analysis Platform (LEAP®) software. The findings of Mondal et al. [10] are based on a comprehensive modeling approach. To forecast electricity demand, three scenario alternatives were developed in this study. One of the three scenarios is an efficient lighting scenario. Electricity savings in the household sector of 289 GWh, 1265 GWh, and 3061 GWh in 2020, 2025, and 2030, respectively, in an efficient lighting scenario. Ac-cording to the findings of this study, an efficient light bulb in the residential sector would reduce electricity demand. Feisal Mirza et al. [11] estimated and analyzed the efficiency dynamics of power companies after the 2006-2013 reforms. The goal is to improve the power sector's technical and financial performance. According to the results of the fixed effects stochastic frontier analysis, the technical efficiency of utilities increased by 4.8%. This investigation contends that the profitability of electric utilities can be improved by changing the general sizes of tasks as well as the sizes at the division and sub-division levels for activity regulation to achieve energy-efficient results. Syed Ali Raza et al. [12] investigated the energy growth nexus in Pakistan using annual time arrangement information data from 1973 to 2013. According to the findings of this study, energy conservation strategies will have a negative impact on trade execution. Faisal Mirza et al. [13] analyze the effects of various electricity conservation strategies on Pakistan's industrial and administrative divisions. It was also discovered that policies that encourage energy efficiency have a long-term positive impact on sectoral output. As a result, rather than implementing direct consumption curtailment policies to bridge the demand-supply gap, the government should take steps to improve the economy's energy efficiency.

Gordhan Valasai et al. [14] discussed the energy situation, policy drivers, and plans. To address the current electricity crisis, four steps are established and suggested for the government to take to bridge the demand-supply gap and achieve sustainable electricity for the country. One of the steps is "undertaking energy conservation and efficiency Programs". This step provides that there is huge energy-saving potential that can be achieved from energy conservation and energy efficiency across all consumers group. Gul and Qureshi et al. [15] investigated the electricity demand for residential appliances such as lightning, fans, motors, refrigerators, air conditioners, and other devices. By 2030, the residential sector's electricity demand is expected to be around 81 TWh after utilizing the energy-saving potential of end-use appliances and 180 TWh without utilizing energy-saving potential. Similarly, Veena Subramaynm et al. [16] focused on energy efficiency as well. The author created an energy efficiency layout that comprises two schemes first one is an efficient appliance and the other one is efficient lightning. The second scheme (efficient lighting) is further subdivided into Light 1 and Light 2 schemes. In the light 1 and light 2 schemes, all current light bulbs are changed with compact fluorescent lamps and incandescent lamps, with energy intensities of 60% and 75%, and 85% (considered 80% in tests). These advancements in technology and appliances will have improved by 30% of the potential by the end of the study period. Gul Qureshi et al. [17] identify potential zones in Pakistan's household sector where efficient developments will result in significant energy savings and, as a result, financial savings for consumers and society as a whole. The investigation focuses on domestic power usage examples to identify areas where there is room for achieving high-effectiveness goals. Zaidi et al. [18] evaluate the impact of different electricity conservation measures on Pakistan's industrial and administrative divisions. Furthermore, energy efficiency should be incorporated into the standard of energy strategy, and specific laws should be enacted to establish organizations and develop strategies to aid in the effective protection and efficient use of limited energy resources.

All above studies are focused on reducing energy demand in Pakistan by incorporating energy efficiency measures but none of the studies available by taking economic measures like GDP growth for finding the exact energy demand of Pakistan, however international studies like Lin Chen et al. [19] suggested that if the legislature does not reasonably deal with the economy, energy consumption will reach 2558.97 million tones of oil equivalent in 2020 to 2594.18 million tones of oil equivalent in 2030 worldwide. Alongside, Pakistan faced massive power outages in 2010, resulting in a loss of GDP and the unemployment of millions of people in the industrial sector [20], [21]. So, there is a dire need to develop a key link between energy demand and the economy of Pakistan for maintaining the GDP of the country and employment in the industrial sectors.

This study is structured into four (04) sections. Section 2 covers a detailed methodology for implementing the concept of energy demand and economy for the period 2023 to 2050 under the reference, low economic growth, medium economic growth, and high economic growth scenarios using LEAP® software. Section 3 presented the complete results with proper analysis and finally, the conclusion is given in section 4.

2 Material and Methods

The fundamental goal of this prediction is to achieve quick and long-term growth for Pakistan's electrical sector, users, and consumption. The research flow diagram of this study is given in Figure 1. The methodology is developed based on the LEAP® tool. LEAP® is an included energy-environment modeling structure [22]. It can be used as an energy accounting framework, which gives an objective and methodical draft of an energy system, evaluation of abatement expenses, and environmental effects [22]. The data can be built starting from the demand area to the supply area. The model can be used to analyze data over short to long-term consumer planning (10 or 40 years) [23]. LEAP® model, which is broadly used to forecast demand and provides energy generation by creating different scenarios and can be used for environmental changes [24]. In this study, electricity consumption is forecasted for domestic, industrial, commercial, agricultural, and other sectors during the year (2023-2050). The impact of GDP, GDP growth rates, and the number of consumers of all sectors are considered in finding energy consumption under the four scenarios namely reference (REF), low GDP growth, medium GDP growth, and high GDP growth keeping 2023 as the base year. Energy scenarios provide a framework with numerous groupings of technology options and their implications for exploring their future energy perspectives. Scenarios have been developed in the past to study future developments under a set of specified conditions. GDP was used as the best approximation for associating electricity demand with economic activity. A detailed description of the scenarios is given below:

1) Reference scenario: The main aim of this reference scenario scheme is to forecast subsequent electricity demand through an analysis of current government policies and strategies [9].
2) Low GDP growth scenario: In this scenario, the GDP rate is consistent with recent GDP growth trends, imply-ing that the Pakistani economy would continue to develop at the same rate as in the past 25 years. The actual GDP of Pakistan is maintained at the rate of 3.56% in 2013 and it will continue at this level through 2017 [25].
3) Medium GDP growth scenario: Under this scenario, there is closely examined the GDP for the last 26 years and found that the GDP growth rate remains close to 5.79% [26].
4) High GDP growth scenario: In this scenario, the level of economic development of the country is analyzed. The maximum growth rate of GDP is 10.22% [27].

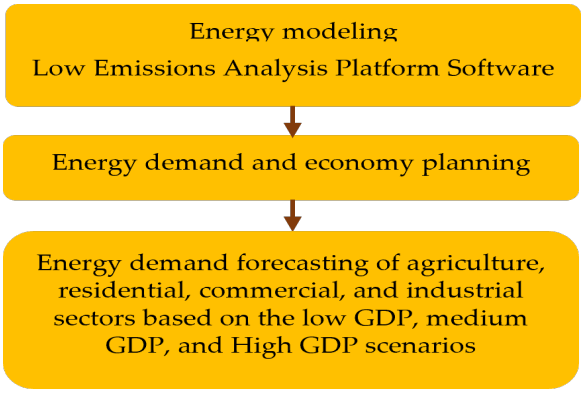

Fig. 1: Research flow diagram

Modeling of energy scenarios is extremely data acute and LEAP® a broad in-built data foundation along with the structure to hold the energy flow characteristics from the reserves to final end-use to balance out the energy run and consumption [28]. In LEAP® software, the input data set consists of various modules such as the main assumptions, energy demand, energy transformation, and resource modules [29]. In the assumption module, the key variables are required to provide independent parameters such as demographics, economic data, and related inputs. The data in LEAP® is used in a hierarchical format which consists of four different levels such as (Domestic, industrial, commercial, agriculture, and others). The final energy intensity of any sector is calculated using the amount of energy consumed in that year as well as the sector's GDP value for that year [30] which is given in Figure 2.

The final energy intensity is expressed in million MWh in this analysis. The following equation is used in the LEAP® model to estimate the energy demand [31].

$$ED_z = \sum w \sum y \; IE_{zwy} \times LA_{zwy} \qquad (1)$$

Where ED_z is the energy demand, IE_{zwy} is the intensity of energy of each sector, w, y is technology and z is the type of fuel. LA represents the level of activity of z fuel through the utilization of w, y technology.

3 Results and Discussion

In the reference scenario, the industrial, agriculture, and total GDP were 52.3, 53.6, and 280 billion US dollars and are projected to be 355.7, 190.3, and 1041.8 billion US dollars in 2050. Industrial GDP increased 6.8 times in 2050 as compared to its base year GDP value. The agriculture and total GDP increased by 3.55 and 3.72 by the year 2050 as compared to its base

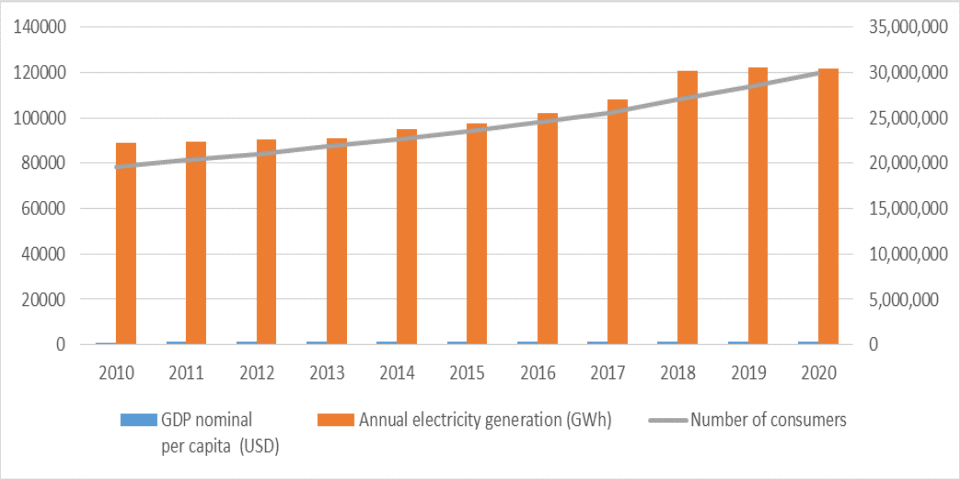

Fig. 2: Consumers, electricity generation, and GDP data of the last ten years

year values. Energy demand increased from 137.97 million MWh in 2023 to 1,244.75 million MWh in 2050 as shown in Figure 3.

Sector-wise GDP under the high GDP growth scenario is higher as compared to the other scenarios because of the high GDP growth rate. The industrial and agriculture GDP is 11.1 and 4.08 times increased by the year 2050 from its base year. The total GDP is projected to increase 8.50 times in the year 2050. Energy demand under a high GDP scenario is increased from 137.97 million MWh in 2023 to 1,894.83 million MWh in 2050 as shown in Figure 4.

Industrial GDP under reference and medium GDP growth scenario are almost the same only a difference of 1.2 billion USD. The agriculture GDP under the medium growth rate scenario is 2.5 times lesser than compared with the agriculture GDP under the reference scenario. The total projected growth of 5.79% GDP is used which is 40% less than the total GDP growth of the reference scenario till 2050. Energy demand under the medium GDP scenario is reduced from 1,244.75 million MWh to 652.17 million MWh in 2050 as shown in Figure 5.

The industrial GDP of the reference scenario is 1.58 times greater as compared with the industrial GDP of the low GDP growth rate scenario, while the agriculture GDP of the reference scenario is 2.2 times greater than the low GDP growth rate scenario till 2050 because as per Pakistan economy survey 2015-2016, due to negative growth in cotton ginning, and crops is noticed in 2016 so the overall growth was -0.19% further, which stabilized at 0.3% at the end of 2016 [32]. Energy demand under the low GDP scenario is increased from 137.97 million MWh in 2023 to 374.79 million MWh in 2050 as shown in Figure 6.

The domestic sector is a major consumer of electricity which was consuming around 48% of electricity out of total electricity consumption in 2023 and the second-largest consumer of electricity is the industrial sector which was consuming around 25% of total electricity consumption. Similarly, commercial, agriculture, and others were consuming 7%, 8%, and 12% in 2023 and are projected to be 14%, 10%, and 14% in 2050.

4 Conclusion

This study identifies the key relationship between energy demand and the economy of Pakistan. Future energy demand projections are forecasted for the period 2023 to 2050 under the reference, high GDP growth rate, medium GDP growth rate, and low GDP growth rate scenarios using the Low Emissions Analysis Platform (LEAP®) software. LEAP software occupies the energy demand module which requires the past energy consumption data from 2010 to 2022 in the current account database and GDP growth rates in the alternative scenarios for the year 2025 and onwards. It is found that energy demand and the GDP of the country have a direct relationship as one quantity increases, the other one also increases, and vice versa. The important points drawn from this study are listed below:

- Under the reference scenario, the total GDP of the country was 280 billion US dollars in 2021 which then increased to 1041.8 billion US dollars by 2050, hence energy demand also increases from 137.97 million MWh in 2023 to 1,244.75 million MWh in 2050.
- Under the high GDP scenario, energy demand is increased from 1,244.75 million MWh to 1,894.83

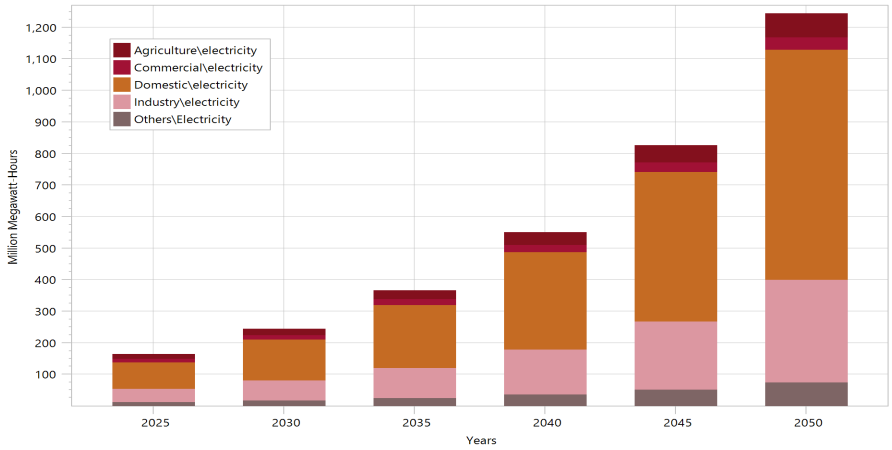

Fig. 3: Energy demand projection under the reference scenario

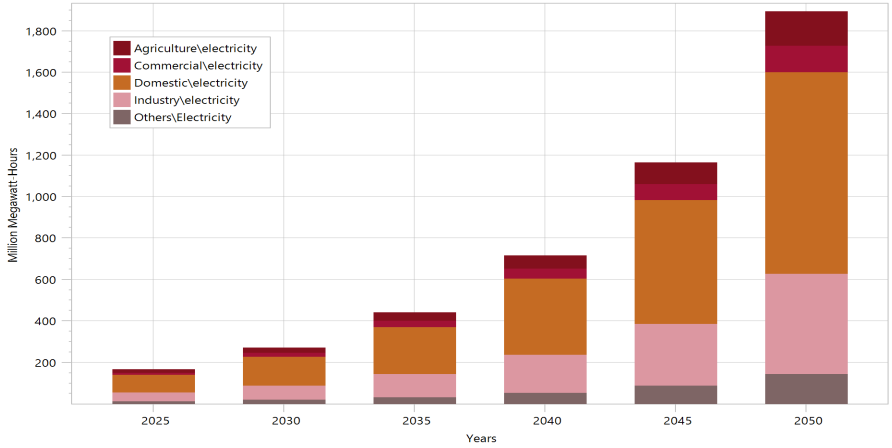

Fig. 4: Energy demand projection under the high GDP scenario

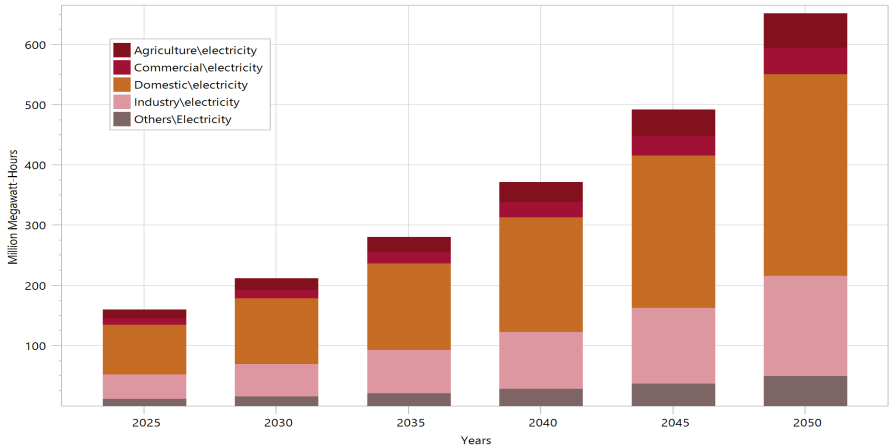

Fig. 5: Energy demand projection under the medium GDP scenario

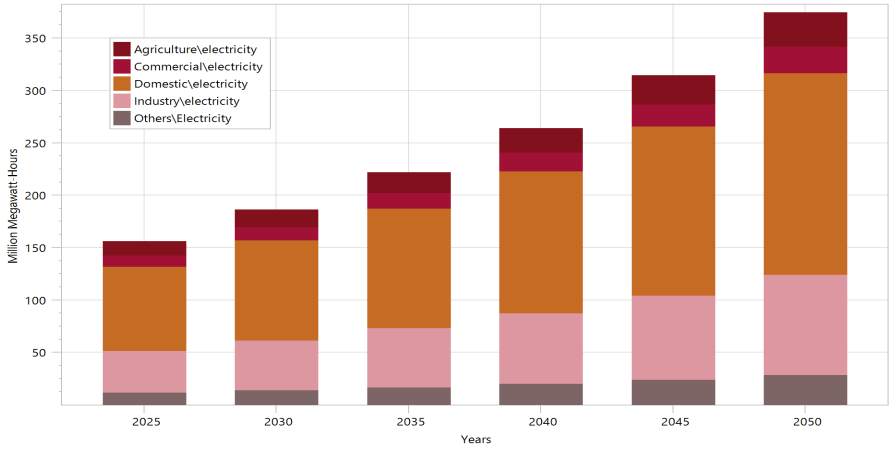

Fig. 6: Energy demand projection under the low GDP scenario

million MWh by 2050 because the GDP of the country is projected to increase 8.50 times in the year 2050 as compared with the reference scenario.

- Under the medium GDP growth scenario, 40% of GDP is reduced as compared with the reference scenario, hence energy demand also reduces from 1,244.75 million MWh to 652.17 million MWh by 2050.
- Under the low GDP scenario, only 3.56% of GDP growth is considered for estimating future energy demand, so energy demand under this scenario was found to be very low 374.79 million MWh as compared with the medium GDP growth scenario (to 652.17 million MWh) and high GDP growth scenario (1,894.83 million MWh).

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