IEP REPORT-1

PAKISTAN ENERGY DEMAND FORECAST (2021-2030)

Integrated Energy Planning for Sustainable Development (IEP)

Ministry of Planning Development & Special Initiatives
Government of Pakistan

October, 2021

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INTEGRATED ENERGY PLANNING FOR SUSTAINABLE DEVELOPMENT (IEP)

The Government of Pakistan (GoP) has envisioned an open, competitive private sector-led energy sector providing reliable, least-cost energy supplies for meeting anticipated demand growth. Integrated energy planning (IEP) is an effective and appropriate tool for realizing the government's vision of developing a sustainable, cost-efficient energy sector that best meets the country's strategic and socioeconomic needs and rapidly growing energy demand.

IEP Process

The goal of implementing IEP in Pakistan is to build the capacity of GoP institutions and relevant stakeholders for analysis-based decision making. Implementation of IEP will create capability at the government level for long-term development strategy as well as medium- to short-term planning. It will also enable viable inter-agency coordination mechanism for identifying, resolving and preempting anomalies, establishment of web accessible reliable, consolidated and up-to-date database of key energy sector information that will provide more consistent, current and reliable inputs for planning, modeling, and assessment activities by key energy sector stakeholders to avoid ad-hoc, siloed planning and help viable target setting for detailed subsector planning.

Contribution(s):

- The report has been developed by the Energy Planning Resource Centre (EPRC), M/o Planning, Development & Special Initiatives:
- The authors are Muhammad Saad Moeen, Forecasting Specialist, Farhan Ahmed Memon, Sr. Research Associate (Policy), Muhammad Ahmad Yousaf, and Muhammad Shahid (Research Associates), and data support is provided by Jawad Ali Qadir, Data Management Specialist.
- Special thanks to Mr. Waqas Bin Najib, Member (Energy), Planning Commission, Mr. Inayat Ullah Qureshi, Chief (EF&E)/Project Director (IEP) and Mr. Aftab Ahmad Awan, Deputy Chief (EF&E) for technical guidance and supervision.
- EPRC team would like to acknowledge the Pacific Northwest National Laboratory (PNNL), Department of Energy (DOE), United States team for providing their technical expertise in evaluating results and providing valuable insights to improve the report.

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Message from Member (Energy), Planning Commission

Developing countries with high dependence on imported energy must improve their planning capability to optimize their energy sectors. Such countries with often vulnerable economies may have to have pay very high cost of poor planning. Pakistan seems to have learnt this lesson the hard way. Suboptimal planning over the past few decades has resulted in an extremely high-cost energy that is neither affordable nor reliable.

Some of the indicators of the poor energy strategy can be seen in the outcomes like, periods of under and overcapacity of supply sources, imprudent use of natural gas for industrial captive power and transportation, lack of significant E&P activity, extremely high dependence on imported fuels and unreliable T&D infrastructure for both electricity and natural gas. On the other hand, poor demand side planning has allowed growth of mostly non-productive demand of energy – comprising mostly of inefficient space cooling and heating as opposed to industrial or other economic activities.

Energy demand forecasting is a critical capability to improve medium- and long-term planning capacity. Currently available models and datasets do not provide a reliable demand forecast. This study reviews and documents the available models and presents a basic forecast model of various energy sources.

I hope this study is the first step towards developing a robust integrated energy model that supports policymaking to minimize cost and increase reliability. National Electricity Policy, recently approved by Council of Common Interest (CCI), lays the foundation of a least-cost growth in the electricity sector. An integrated energy model should help develop a least-cost energy sector, optimizing all energy sources under different scenarios.

Waqas Bin Najib

Member (Energy) at the Planning Commission of Pakistan

Executive Summary

The energy sector of Pakistan plays a vital role in the economic development of the country and directly affects all other economic sectors of Pakistan. Given the socioeconomic impacts of energy, optimal planning for sustainable energy is imperative. Achieving a sustainable energy mix and ensure an uninterrupted energy supply requires the development of a medium- and long-term planning framework comprising a "future energy demand forecast" followed by "energy resource management."

This report aims to start addressing the dire need for primary energy demand forecasting and provide the future energy demand (2021–2030) for all energy sources (oil, coal, natural gas, liquefied natural gas (LNG), liquefied petroleum gas (LPG), and electricity) across all economic sectors of Pakistan. The review of existing energy sector forecasts published by various stakeholders in their official reports, e.g., Indicative Generation Capacity Enhancement Plan (IGCEP), Power Market Survey (PMS), Pakistan Energy Outlook, Pakistan Oil Report, and Sate of Regulated Petroleum Industry Report, is provided.

The long-term energy demand forecast presented in this report was developed by assessing the final energy consumption trends by economic sector, and the demand model is based on a regression model for electricity and all fuels by economic sector. The demonstrated model computes the final energy consumption in correspondence to gross domestic product (GDP) growth, energy prices, population, and urbanization for electricity and all fuels. Furthermore, the underlying assumptions are based on economic and industrial development, population growth, volatility in energy prices, and energy consumption scenarios prioritized by the Government of Pakistan; e.g., furnace oil (FO) consumption for power generation, National Electric Vehicles Policy-2019 targets for electric vehicle penetration, and unmet primary energy demands.

The forecasting model uses historical annual energy consumption data by category (domestic, commercial, industrial, etc.); total and sector-wise GDP (agriculture, industrial, and services), energy prices by economic sector, population, and urbanization for the period of 1986–2020; and projections of exogenous variables (GDP, population, crude, and oil prices) from 2021 to 2030 obtained from various publicly available sources and energy sector official reports. The validity of the forecasting model and prediction bias are also checked by the retrospective forecast by using training data from 1986 to 2010 and test data from 2011 to 2020.

The energy demand forecast results are presented in two ways: by primary energy source (oil, natural gas including LNG, LPG, coal, and electricity) and by each economic sector. Demand forecast results by source suggest that the overall primary energy demand of the country (including power generation and feedstock requirements) will increase from 75.5 million tons of oil equivalent (Mtoe) to 99.2 Mtoe by 2030 with a major share of natural gas (including LNG) and oil, followed by coal and electricity and LPG.

The energy demand forecast by economic sector also provides a detailed discussion of the historical consumption patterns and future demand projections for all energy fuels in the domestic, commercial, industrial, agriculture, and transport sectors. These demands forecast results follow the same historical consumption trend of oil, natural gas, LPG, and electricity in the domestic, commercial, industrial, and transport sectors, whereas increased demand for electricity is predicted in the agriculture and transport sector replacing the demand for oil by 2030. In addition, fossil fuel requirements for thermal power generation (2021–2030) are provided based on the National Transmission and Despatch Company's IGCEP 2021 and the K-Electric expansion plan for future thermal power generation in the country.

The energy demand forecast model developed in this report has a number of limitations, including a lack of monthly data for energy consumption, an exclusion variable bias, and a weak estimation strategy. In the future, energy demand forecast results will be improved by capturing the seasonal variations in energy source consumption patterns. To this end, the process of collecting energy consumption data on a monthly basis from key energy sector stakeholders has already begun. Furthermore, demand forecast results will be improved by adding more key variables to the forecasting model to reflect the consumption patterns of consumers. The least-square regressions are not resistant to outliers, so reliance on an autoregressive model, such as autoregressive moving average (ARMA), an autoregressive integrated moving average (ARIMA), and a vector autoregressive (VAR) for the smallest prediction bias in the result estimates, is required.

In future, an accurate and reliable IEP model will help to run multiple policy scenarios i-e natural gas depletion, Electric Vehicles penetration, shifting of industry from Captive Power Plants towards National Grid, shutdown of oil refineries and import of POL products in Pakistan. These policy analyses would help to assess economic implications, generate policy recommendations for policymakers in the energy sector. Moreover, planning based on reliable and evidence-based energy forecast could help pave the way for balanced energy supply-and-demand management at different levels.

1. Introduction

Energy consumption has been demonstrated to increase relative to population growth and industrial and economic development in many under-developed countries.[1] In some cases, the pressures of growing populations and economic and industrial development have caused energy demand to increase more rapidly than energy supply. Currently, the world energy consumption of 9,937 million tons of oil equivalent (Mtoe) largely depends on oil, followed by electricity, natural gas, and coal (see Figure 1). Of the total world energy consumption, China (21 percent), USA (16 percent), India (6 percent), and Russia (5 percent) are the major energy consumers (see Figure 2). Pakistan, having less than 1 percent share in world energy consumption, meets its energy demand through imported and indigenous resources.

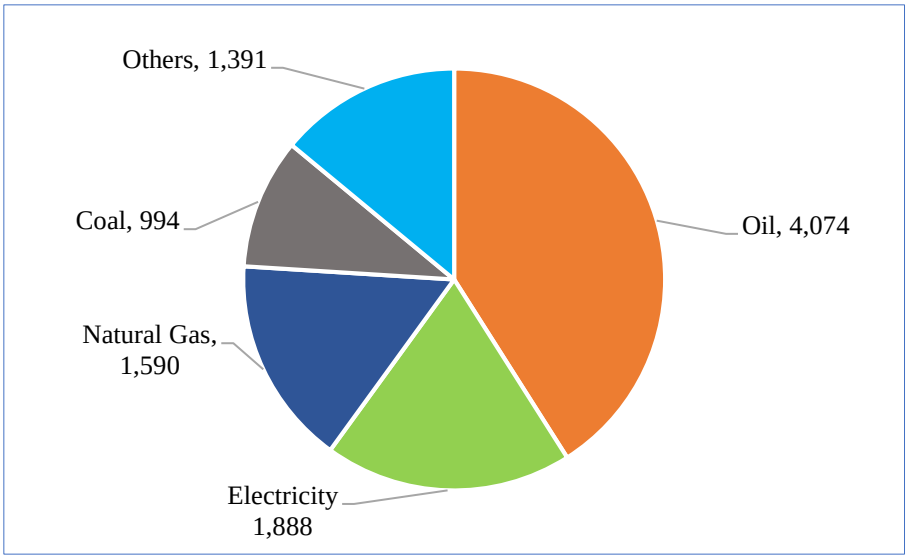


Figure 1. World Energy Consumption by Source (Source: International Energy Agency)

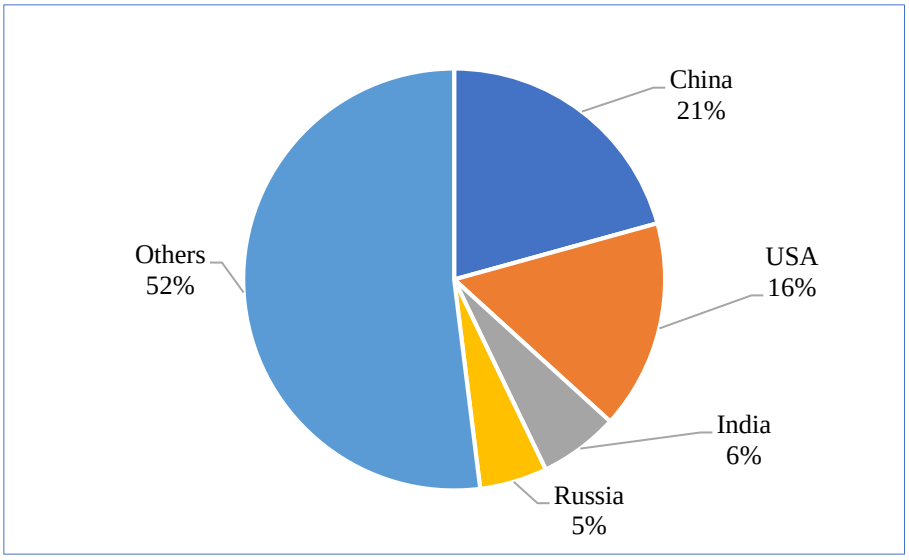


Figure 2. Energy Consumption by Major countries (Source: International Energy Agency)

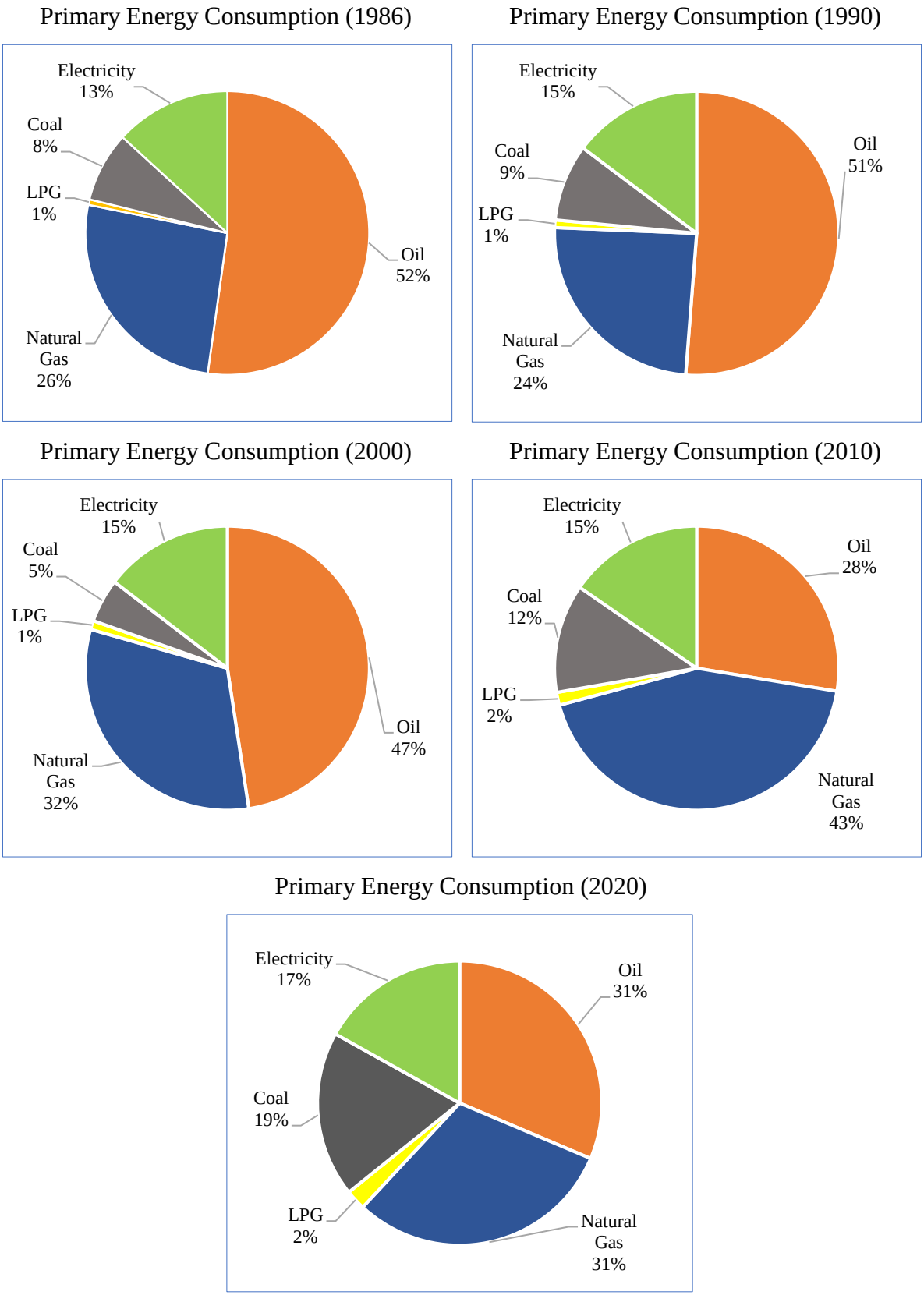


Figure 3. Pakistan's Energy Consumption by Source (Source: Energy Year Book [1986-2020])

Statistics shows that final energy consumption in Pakistan increased from 12 Mtoe in 1986 to 52.17 Mtoe in 2020, with a 4.4 percent annual compound growth rate (ACGR).[2] Increasing energy demand and limited supply of modern energy sources have become a challenge and major policy concern in Pakistan.[3] Pakistan's total primary commercial energy supply[a] is around 80.62 Mtoe, which includes indigenous resources (46.56 Mtoe) and net imported energy resources (34.06 Mtoe). The primary energy supply consists of 33.1 percent natural gas, 22.6 percent oil, 18.2 percent coal, 14.5 percent electricity derived from hydro, nuclear, renewable, and imported power, 10.3 percent imported liquefied natural gas (LNG), and 1.3 percent liquefied petroleum gas (LPG). The final energy consumption[b] is 52.17 Mtoe and the remaining 28.45 Mtoe is used in energy transformation.[c] Of the transformation usage (28.45 Mtoe), 2 percent is auxiliary consumption by the energy sector; 65 percent is transformation consumption by gas processing plants, petroleum refineries, and electric power stations; 21 percent is transmission and distribution (T&D) losses; and 12 percent is energy consumption for non-energy uses (fertilizers, feedstock, lubes, etc.) and statistical difference.

A historical review of the data shows that oil and gas remain the most consumed sources of energy, followed by electricity, LPG, and coal. Currently, the final energy consumption percentages by energy source are 31.4 percent oil, 30.5 percent natural gas sources including LNG, 18.9 percent coal, 16.9 percent electricity, and 2.3 percent LPG.[4] Similarly, statistics for final energy consumption by economic sector show that the industrial sector is consuming the highest proportion of energy at 36.7 percent, followed by the transportation sector at 30.3 percent, the domestic sector at 24.4 percent, the government sector at 3.7 percent, the commercial sector at 3.4 percent, and agriculture at 1.5 percent.[5] A detailed review of the energy sector reveals that energy forecasting should be considered for all fuels and electricity instead of focusing only on the electricity forecast for energy sector planning. Further, energy forecasting for all fuels and electricity by economic sector in Pakistan can help decision-makers understand the volume and trend of future energy consumption and help ensure a balance between energy supply and demand.

This report recognizes that energy forecasting challenges are immense and several methodologies, assumptions, and statistical techniques are available for computing energy

[a] Primary Energy Supply: An energy form found in nature that has not been subjected to any conversion or transformation process.
[b] Final Energy Consumption is the total energy consumed by end users such as household, industrial, commercial, agriculture, etc.
[c] Energy transformation involves processes that convert energy from one type (e.g., kinetic, gravitational potential, chemical energy) to another.

projections (for all fuels and electricity by economic sector). These challenges can be addressed with perseverance and a coordinated strategy that explicitly takes into account a review of the existing forecasting practices/tools in the country. This report represents a first effort to develop countrywide energy projections by sector for Pakistan. The authors hope that input and suggestions by other stakeholders will help guide and strengthen these forecasts and future scenario assessments. The authors hope that these energy forecasts can help transparently generate policy recommendations for the energy sector that are based on consistent data input and assumptions. We also hope these projections provide insights into future market directions and requirements for sound investment decision-making by both public and private sector stakeholders that can help in maximizing the long-term socioeconomic benefits for the country.

1.1 Need for Energy Forecasting

Energy forecasting is required for efficient energy planning to balance supply and demand[6]. Energy forecasting plays a key role in both short- and long-term energy planning for different energy-related stakeholders and policymakers.[7] Moreover, demand forecasting plays a vital role in energy supply-and-demand management for both government and private sector entities.

Inefficient forecasting may lead to unbalanced energy supply and demand, which may have negative impacts on operational cost, network safety, and the service quality of the supply network.[8] Underestimation of energy demand can affect a society's overall economy, energy resources, power outages, and daily life. Likewise, overestimation of energy demand may lead to overbuilt, unused capacity and wasted energy resources, and financial losses. Hence, suitable energy forecasting models need to be used to forecast future energy consumption.[9] Forecasting plays a significant role from the perspective of energy pricing as well. Energy price variation is heavily dependent on the supply-and-demand balance.[10]

The importance of energy demand management has become more crucial in recent decades as certain energy resources are being depleted, emissions are increasing, and global developments toward the implementation of renewable and green energies are not yet fully applied. Thus, energy forecasting is the most important topic in the demand management area.[11]

1.2 Review of Forecasting Methodologies in Pakistan

The selection of a forecasting model is mostly based on data availability, the objectives of the tool and planning exercise. For instance, temperature, humidity, and precipitation may

differ hourly and be used in short-term forecasting. However, socioeconomic variables such as gross domestic product (GDP), gross national product (GNP), and population may be measured annually and considered in long-term forecasting. A review of forecasting methodologies for the most applied energy forecasting methods is given for comparison in Table 1.[12]

Table 1. Review of Forecasting Methodologies

Methods	Category	Approach
Regression model	Causal	• Regression models determine a forecasting function by calculating a dependent variable value based on one or more independent variables.
Time-series model	Historical	• Time-series forecasting is used to predict the future values of a variable based on its previously observed values.
ARMA, ARIMA, SARIMA	Historical	• Stationary time-series manner can be forecasted by ARMA. • Non-stationary time series can be forecasted by ARIMA. • SARIMA is used to incorporate both seasonal and non-seasonal factors.
Support vector machine (SVM)	Historical	• A support vector machine is a machine learning method, which has the capabilities of classification and regression.
Artificial Neural Network (ANN) Models	Causal	• ANN model is a data driven approach. It uses the data to capture the link between different input and output variables to forecast the output values.
Grey (gray) prediction	Historical	• Grey method is used for systems with small samples or poor information by using correlation coefficient method, the regression model, and Granger causal relation.
Genetic Algorithm (GA)	Historical	• The GA is one of the most famous evolutionary algorithms. It is used to forecast total and sectoral (mainly industrial) electricity demand based on different economic factors.

ARIMA = Autoregressive Integrated Moving Average; ARMA = Autoregressive Moving Average; SARIMA = Seasonal Autoregressive Integrated Moving Average

Source: Ghalehkhondabi, I., Ardjmand, E., Weckman, G. R., & Young, W. A. (2017). An overview of energy demand forecasting methods published in 2005–2015. Energy Systems, 8(2), 411-447.

Note: The paper reviews the most-used energy demand-forecasting methods that have been published as research articles between 2005 and 2015.

1.3 Scope of the Study

Using models to accurately forecast future energy consumption trends—specifically when nonlinear relationships exist—is an important issue for the forecasting process. Several techniques have been developed based on econometric methods to accurately predict future energy consumption. The key objectives of this study include the following:

- Review existing official energy forecasting models/techniques in the country.
- Develop improvements in energy forecasting and calibrate historical data, as required.
- Forecast the primary energy demand (2021–2030) by fuel sources, including oil, LPG, gas including LNG, coal, and electricity.
- Provide information to support understanding of the policy implications to meet future demands for efficient energy supply-and-demand planning in the country.

The report is organized as follows. Section 2 reviews existing demand forecasts for the energy sector in Pakistan. Section 3 illustrates our energy forecasting framework; details the assumptions, data, estimation model, and elasticity coefficient for our projections; and provides a retrospective forecast for model validity and verification. Section 4 provides results and discussions of our energy forecast for all fuels and electricity by economic sector. Section 5 examines the limitations of the methodology, data, and model, and Section 6 concludes the discussion by highlighting key recommendations and the way forward.

2. Review of Existing Energy Forecasts

This section explains the existing energy forecasts in Pakistan based on official reports developed by energy sector entities. For instance, the National Transmission & Despatch Company (NTDC) is currently doing an electricity forecast for the country. Likewise, the Pakistan Institute of Petroleum (PIP), Oil Company Advisory Council (OCAC), and Oil and Gas Regulatory Authority (OGRA) are also publishing their reports about the forecast for all fuels and electricity. The results of these reports are summarized for comparison in Table 2 (at the end of this section), which considers the scope of the report, plan period, input data and its sources, forecasting scenarios, location and sectors, key parameters and determinants, and forecasting methodology.

2.1 Indicative Generation Capacity Expansion Plan (IGCEP)

The IGCEP report is developed by NTDC and is a comprehensive view of the long-term forecast for electricity generation and peak demand (MW) for the whole country except K-electric (KE). The latest forecast is available from the IGCEP-2021 report,[13] which provides forecasts for the period from 2021 to 2030. Key facts are given below:

- Three different scenarios (Low, Normal, and High) are developed for long-term demand forecast planning based on GDP growth rates.
- Input data are based on historical data from 1970 to 2020 and growth projections are articulated for the plan period.
- Electricity consumption and tariff data are categorized into domestic, commercial, industrial, and agriculture categories.
- Key parameters are GDP at factor cost (total and sector-wise), real prices, and lag values of electricity consumption.
- An econometric approach using the Ordinary Least Square (OLS) method is considered for the estimation model.

2.2 Power Market Survey (PMS)

The PMS report is a medium-term forecast of electricity sale, generation (GWh), and peak demand (MW) for network planning developed by NTDC. The latest PMS report predicts values for 2019 to 2028[14] based on the following steps:

- Conduct PMS forecasting for the electricity sale, generation (GWh), and peak demand (MW) for distribution companies (DISCOs) and then consolidate the results for the total system.
- Acquire gross consumption by consumer categories from the service meter readings from DISCOs.
- Use the following parameters and determinants: consumption growth rate, T&D losses, load factor, diversity factor, and unserved energy data collected from each DISCO as an integral part of the forecast model.
- Base parameters on consumer categories such as domestic, commercial, industrial, agriculture, and public lighting.
- PMS forecast report has three basic scenarios that include providing computed load forecast:
  - Base forecast: incorporating the effect of load shedding
  - Low forecast: without incorporating the effect of load shedding,
  - Forecast with demand-side management (DSM).
- Consider the forecasting method a survey-based PMS model that uses a bottom-up approach for all DISCOs.

2.3 Pakistan Energy Outlook

The Pakistan Energy Outlook, developed by the Pakistan Institute of Petroleum (PIP), provides a long-term forecast for the primary and final energy demand and supply. The latest report provides projections for primary and final energy demand and supply (Mtoe) by energy sources, such as oil, gas, coal, LPG, and electricity, for the plan period of 2021–2044.[15] The report includes a comprehensive review of the following topics:

- The demand and supply forecast of primary and final energy for 2020 to 2044 with five-year intervals.
- The projections for the final energy demand for oil, gas, coal, and net electricity based on expected growth rates computed using the autoregressive moving average (ARMA) model.
- The LPG forecast based on Cumulative Average Growth Rate (CAGR) in line with GDP growth rates.
- Historical data for dependent and independent variables; for instance, total primary and final energy demand of different energy sources, real and per capita GDP growth, growth

in the number of households, industrial GDP growth, high-speed diesel (HSD) and gasoline prices growth, and inflation are based on historical data from 1990 to 2019.

- The forecast based on six scenarios considering various GDP growth rates and improvements. Improvements assumed include reducing electricity transmission and T&D losses, consistent with targets of National Electric Policy 2019, and increased off-grid power generation.

2.4 Pakistan Oil Report

The Pakistan Oil Report is prepared for its OCAC members for information purposes. Pakistan Oil Report, 2017-2018. provides forecasting for petroleum oil lubricant (POL) products from 2018 to 2023.[16] Key points derived from the report are given below:

- The GDP growth rate is assumed to be 5 percent over the next five years.
- Input data are provided by OCAC members such as oil refineries and marketing companies.
- The forecast for POL products, except gasoline and HSD, is based on five years compound annual growth rate of 4.91% percent, which is based on the assumed GDP growth rate.
- The year on year (YoY) moving average of 9% for gasoline and 6% for HSD was considered for projections of gasoline and HSD.
- Forecasting for imported products is calculated based on local production versus the projected demand for gasoline and HSD.

2.5 State of the Regulated Petroleum Industry Report

The State of the Regulated Petroleum Industry Report is developed by OGRA and provides data for the sectoral demand-supply forecast for natural gas. The latest report forecasted gas demand and supply including LNG supply for the period of 11 years from 2021 to 2031.[17] The forecasting methodology is not explained in the report.

Table 2. Review of Existing Forecasts in Pakistan

Report	Scope	Period	Data	Scenarios	Location & Sectors	Parameters & Determinants	Methodology
Electricity Forecast							
IGCEP, 2021 *(NTDC)*	Electricity generation and peak demand projections	2021 to 2030	• Total and sectoral GDP at factor cost & CPI from Pakistan Economic Survey • GDP projections from IMF • Consumer category wise average tariff from DISCOs Performance Statistics by PEPCO-June 2020	• Low, normal, and high growth scenarios	• Whole country *except KE*	• GDP, real price, and lag values	• Ordinary least square/multiple regression approach
Power Market Survey (PMS), 2019 *(NTDC)*	Electricity sale, generation, and peak demand projections	2019 to 2028	• Gross consumption by consumer categories from service meter reading from DISCOs	• Base, low and demand-side management scenarios	• Category wise consumer for DISCOs	• Growth rate of consumption • T&D loss rate • Load factors • Coincidence factors • Unserved energy in the base year 2018	• PMS model using a bottom-up approach
Energy Forecast (Electricity and all Fuel)							
Pakistan Energy Outlook 2020 *(PIP)*	Forecast for primary & final energy demand by source (electricity and all fuels)	2021 to 2044	• GDP, population, number of households from Pakistan Economic Survey • Source-wise energy supply and demand for each consumer category from energy sector entities	• 6 scenarios based on different real GDP growth rates and improvements measures	• Countrywide by energy sources (electricity and all fuels)	• Real GDP growth and lag values	• Autoregressive moving average (ARMA) model • CAGR for LPG

Report	Scope	Period	Data	Scenarios	Location & Sectors	Parameters & Determinants	Methodology
Pakistan Oil Report 2017-18 *(OCAC)*	Forecast for POL products	2018 to 2023	• Oil refineries and oil marketing companies, SNGPL, SSGCL	• Scenario is based on GDP growth	• Countrywide for POL products	• GDP growth of 5% over the plan period	• ACGR based on GDP growth rate • Year on Year moving average for gasoline & HSD in line with GDP growth rate
State Of the Regulated Petroleum Industry 2019-20 *(OGRA)*	Forecast for Demand and Supply of Natural Gas including LNG	2021 to 2031	• Gas consumption from SNGPL & SSGCL	• Base scenario	• Sector-wise demand projections for SNGPL, SSGCL & Independent system	N/A	N/A

3. Energy Forecasting Framework

The long-term energy forecast (2021–2030) described in this report was developed through multiple regressions of energy consumption trends by economic sectors (i.e., domestic, commercial, industrial, agriculture, transport, and other government). Several socioeconomic factors can influence the demand forecast. The factors that were taken into consideration in the projections summarized in this report were: economic development, energy prices, population growth, and urbanization in the country. Our demand model is based on multiple and linear regression models using final energy consumption, GDP growth, energy prices, population, and urbanization. The model consists of the historical trend (1986–2020) of final energy consumption by various economic sectors as an endogenous variable for the forecasting process.

3.1 Assumptions

The major assumptions considered to generate the projections, including economic and industrial development, population growth, and assumptions concerning energy prices were used to develop the model framework. Most of the assumptions are critical, but substantial uncertainties in the future can create risk for the long-term trends, seasonal and short-term variations and volatility in the prices of the underlying assumptions for our analysis are given below:

- Economic development has a direct link to energy consumption. For example, economic growth triggers economic prosperity and changes in peoples' wellbeing, and lifestyle changes can result in increased energy consumption. (see Figure 4 for projected GDP)
- Energy prices have a direct causal relationship with energy consumption. Fluctuations in energy prices will reflect a change in future energy consumption, accordingly.
- Population growth increases the number of energy consumers, which may also increase future energy consumption. (see Figure 5 for population growth projections)
- Urbanization tends to increase energy services such as heating, cooling, lighting, power, and transportation.
- International crude oil prices are linked with local energy sector prices; therefore, the projected trend in energy prices is based on future crude oil prices. (see Figure 6)
- Lag values of energy consumption are also used in the model by considering the dependent variable response to an exogenous variable with time lag.
- Some consumption of energy source (like CNG, FO, and HSD) are experienced as a declining trend in the past and are assumed to be further declining in future consumption.

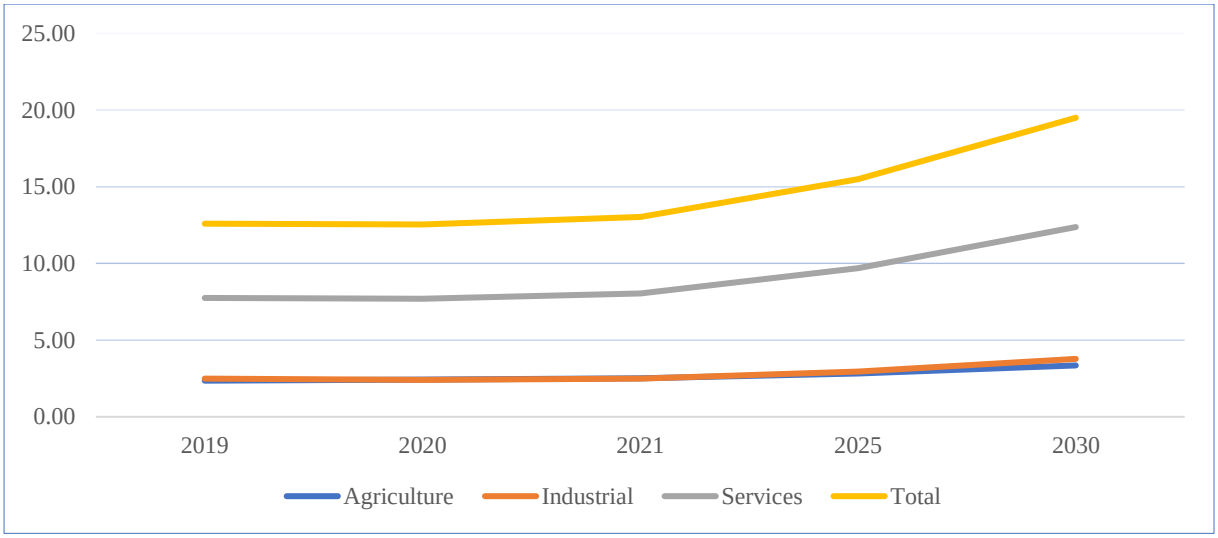


Figure 4. Projected GDP-Million Rupees (2019-2030) (Source: International Monetary Fund)

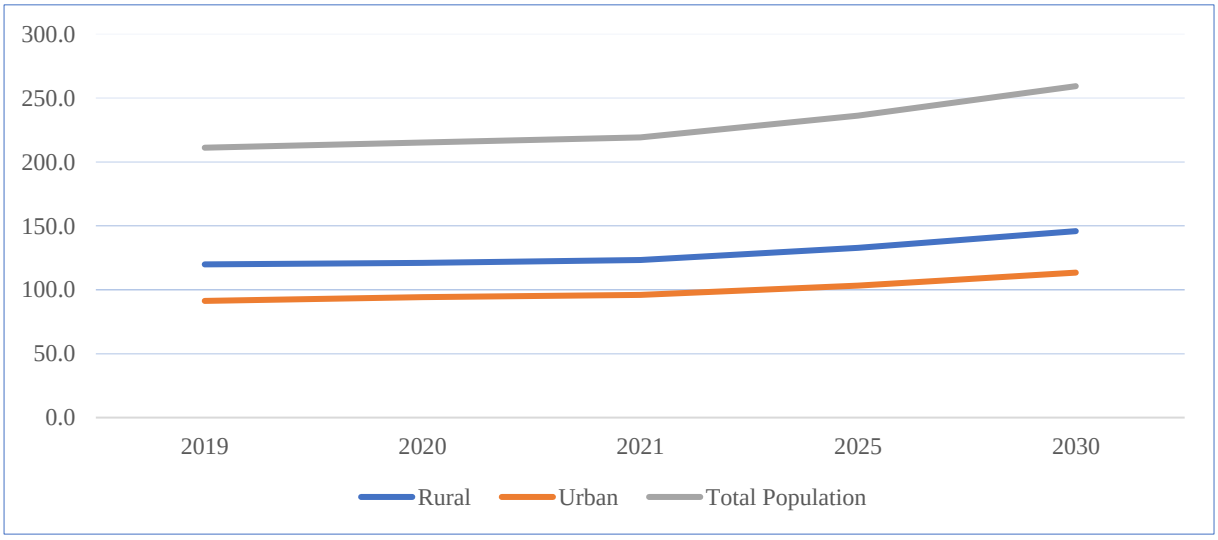


Figure 5. Projected Population-Million (2019-2030) (Source: International Monetary Fund)

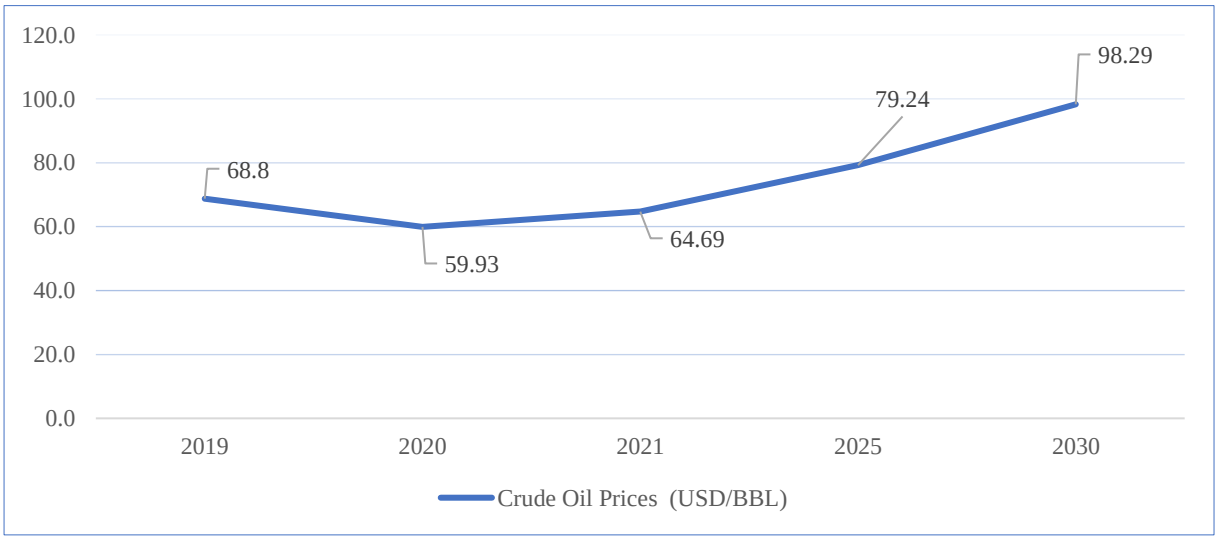


Figure 6. Crude oil Prices (2019-2030) (Source: Energy Information Administration (EIA)

- Consistent with the National Electric Vehicle Policy (NEVP) of 2019, increasing power consumption is based on targeted NEVP electric vehicle penetration. Hence, forecasted power consumption is assumed accordingly.
- Final primary demand is estimated based on current load shedding for electricity[18] and unmet demand for all fuels such as oil, gas, and LPG[19] as mentioned in below table.

Source	Unmet demand (2021-2025)	Unmet Demand (2026-2030)
Electricity	7 %	5 %
Oil	5 %	5 %
Coal	5 %	5 %
Natural Gas	15 %	10 %
LPG	5 %	5 %

3.2 Input Data and Data Sources

The model used an annual final energy consumption by category, total and sector-wise GDP (agriculture, industrial, and services) at factor cost in millions, and energy prices by economic sector, population, and urbanization for the period of 1986–2020. The data have been collected from various sources, including the Pakistan Energy Yearbook by Hydrocarbon Development Institute of Pakistan (HDIP), the Economic Survey of Pakistan, the Ministry of Energy (Petroleum Division), Pakistan State Oil (PSO), OGRA, NTDC, and KE. Moreover, our model also used projections of the exogenous variable such as GDP, population, and crude oil prices from 2021 to 2030 for long-term forecasting (see Table 3).

Table 3. Input Data and Data Sources

Sr. No	Input Data	Data Sources
Historical Data		
1.	Category wise final energy consumption	Pakistan Energy Yearbook by HDIP
2.	Total and sector-wise GDP (agriculture, industrial, and services) at factor cost in millions	Economic Survey of Pakistan, Finance Division, Government of Pakistan
3.	Prices of petroleum products, LPG, natural gas, coal, and electricity by economic sector	Pakistan Energy Yearbook by HDIP, Ministry of Energy (Petroleum Division), PSO, OGRA, NTDC, and KE
4.	Population (Urban, Rural and Total)	Economic Survey of Pakistan, Finance Division, Government of Pakistan
Projected Data		
5.	GDP and Population growth	International Monetary Fund (IMF) https://www.imf.org/en/Publications/WEO/Issues/2021/07/27/world-economic-outlook-update-july-2021#Projections (accessed July 15, 2021)
6.	Crude Oil Prices	Energy Information Administration (EIA) https://knoema.com/infographics/yxptpab/crude-oil-price-

Sr. No	Input Data	Data Sources
		forecast-2021-2022-and-long-term-to-2050 (accessed July 15, 2021)
7.	Thermal based power generation	Indicative Generation Capacity Expansion Plan (IGCEP) 2021 https://nepra.org.pk/Admission%20Notices/2021/06%20June/IGCEP%202021.pdf (accessed June 15, 2021) KE Generation Capacity Enhancement https://www.ke.com.pk/our-business/generation/ (accessed July 15, 2021)

3.3 Methodology and Estimation Model

The selection of a forecasting model is mostly based on data availability, the objectives of the tool and planning exercise. Regression analysis is useful for exploring the causal relations between dependent and independent variables and is widely used for forecasting.[20] Our model is based on single-equation consumption models for energy sources such as oil, natural gas, coal, LPG, and electricity for the economic sector, including domestic, commercial, industrial, agriculture, transport, and other/other government. The model demonstrates in linear-log form connection of the final energy consumption to GDP growth, prices, population, and urbanization:

$$\boldsymbol{Y_{ijt} = \beta_0 + \beta_1 \log(GDP_{jt}) + \beta_2 \log(Energy\ Prices_{\ ijt}) + \beta_3 \left(FEC_{ij(t-1)}\right) + \beta_4 K_t + U_i} \qquad (1)$$

Where,

Y = final energy consumption,
i = energy sources including oil, gas, LPG, coal, and electricity,
j = economic sectors such as domestic, commercial, industrial, agriculture, transport, and other government,
t = time-period,
$FEC_{ij(t-1)}$ = lag values of final energy consumption by category,
GDP_{jt} = GDP by sector (agriculture, industrial, and services),
$Eenrgy\ Prices_{ijt}$ = energy prices by energy source for each category,
K_t = vector for control regressors such as population & urbanization factors,
β_0, β_1, β_2, β_3 and β_4 = regression coefficients, and
β_1 and β_2 = the GDP and price elasticities for final energy consumption.

3.4 Elasticity Coefficients for GDP and Price

Elasticities are calculated for GDP and prices for each energy source. The coefficients are very important because they report the income and price elasticities of energy consumption for each energy source (see Table 4). The energy intensity of the GDP represents the percentage increase in the consumption of each energy source that corresponds with a 2 percent change in the GDP. The expected signs for energy intensity corresponding to the GDP for each energy

source are greater than zero because higher real GDP and GDP per capita correspond to an increase in energy consumption.

Price elasticity of demand is a measure of the percentage change in demand that corresponds with a price change. The expected sign for price elasticities for each energy source is less than zero (except for coal), which implies that higher real prices decrease the energy consumption. A positive correlation of price elasticity for coal indicated that coal does not adapt to the law of demand; therefore, a 1 percent decrease in demand for coal is correlated with a 1 percent reduction in price. This positive correlation may be justified because the non-power-used coal is largely consumed by the brick-kiln and cement industry without substation of any other fuel. Therefore, the coal consumption in the industrial sector does not correspond to price elasticities compared to other fuel sources.

Table 4. Elasticity Coefficient by Energy Source

Sources	GDP	Prices
Oil	0.900	-0.269
LPG	1.963	-0.090
Gas	1.506	-0.075
Coal	0.490	0.357
Electricity	1.304	-0.109

Source: Author's calculation based on estimation model.

3.5 Retrospective Forecast (Model Validation/Check)

The validity of the forecasting model can be checked by two approaches: (1) **the ex-post forecast** (forecast to check with actual existing data to assess the validity of the model[21]) and (2) **the ex-ante forecast** (provides values of the endogenous variables beyond the estimation period and does not use actual values) [22].

Using the ex-post approach, retrospective forecast analyses were performed for 2011 to 2020 to check the validity of the model and prediction bias. For the analyses, data from 1986 to 2010 were used as a training set and data from 2011 to 2020 were considered as a test set. We calculated the mean absolute percentage error (MAPE)[d] for a comparison between actual and fitted values. The results are shown in figure 7 to 10.

[d] $MAPE = \frac{1}{n} \sum_{t=1}^{n} \left| \frac{Actual_t - Forecast_t}{Forecast_t} \right|$

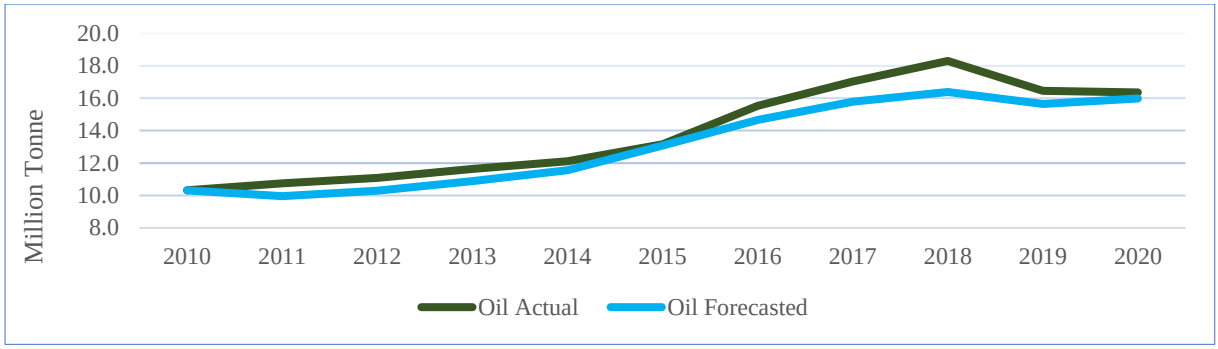


Figure 7. Retrospective Forecast for Oil Consumption (2011-2020) (Source: Energy Year Book, (various issues) and Author's calculations)

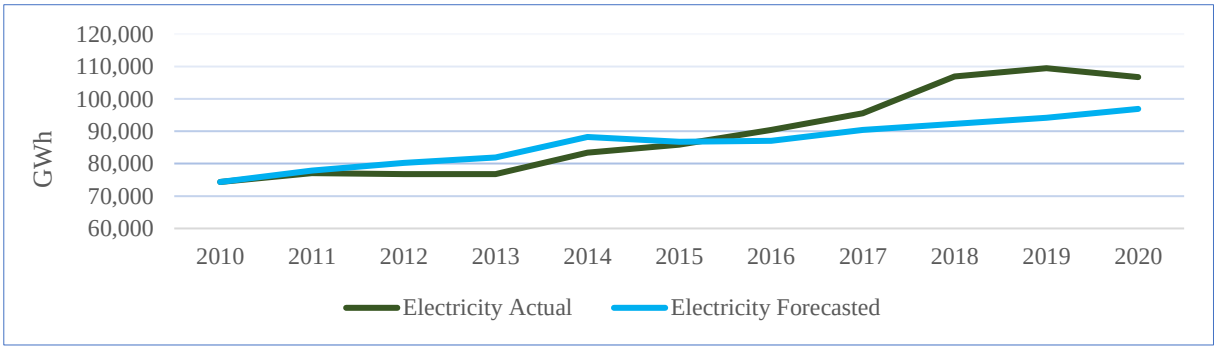


Figure 8. Retrospective Forecast for Electricity Consumption (2011–2020) (Source: Energy Year Book [various issues] and Author's calculations)

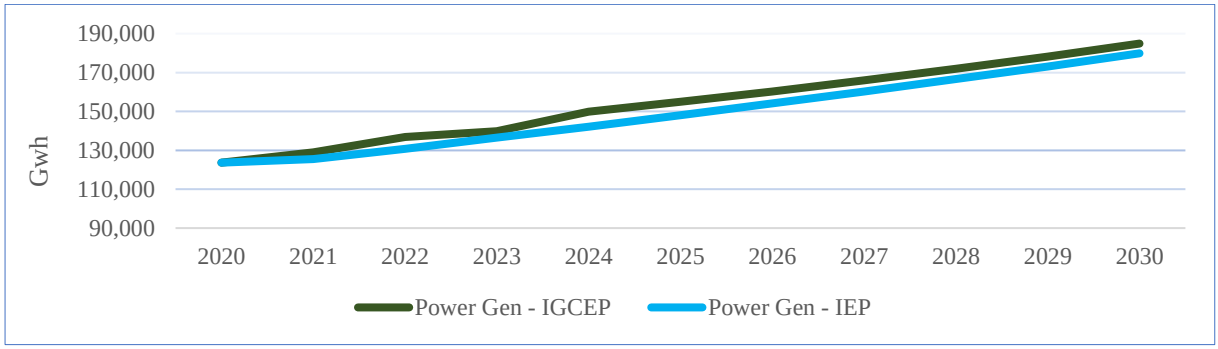


Figure 9. Forecast for Electricity Generation (2021–2030) (Source: Energy Year Book [various issues] and Author's calculations)

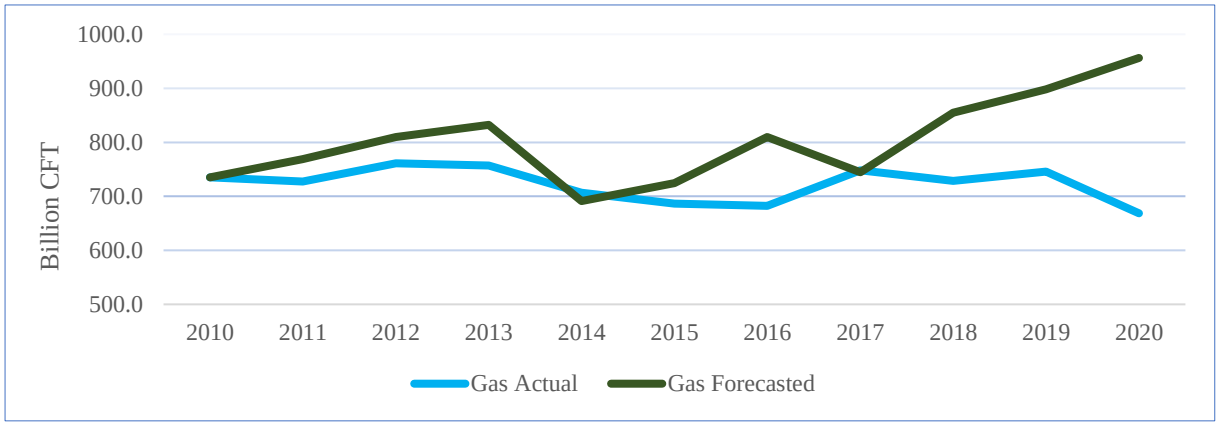


Figure 10. Retrospective Forecast for Gas Consumption (2011–2020) (Source: Energy Year Book [various issues] and Author's calculations)

The results indicate that the MAPE ranges from 5 to 6 percent for the projections of oil and electricity. The results show that forecasting results are consistent with the underlying assumptions and parameters; i.e., GDP, fuel, and electricity prices by economic sector (see Figures 7 and 8).

We also performed future projections for electricity generation from 2021 to 2030 to compare our results with IGCEP-2021.[23] For comparison, the MAPE between IGCEP and our results is 3.6 percent, indicating the results match (see Figure 9).

The model also estimates retrospective forecasts for other fuels such as LPG, gas, and coal for the model authentication/check. The MAPEs for LPG and coal also vary from 5 to 7 percent, which implies that forecasting results correspond to the underlying assumptions and parameters. These results indicate that these sources may not be consistent with energy intensity in the context of GDP, GDP per capita and price elasticity, and other control variables in the model, and there may be other factors that affect the response variable. For instance, actual gas consumption remains low compared to our projections, which indicates that gas consumption may remain lower due to supply constraints and demand management by the federal government[24] (see Figure 10).

4. Results and Discussion

This section discusses the forecast for energy sources for 2021 to 2030. The results are discussed in terms of the energy forecast by source, the energy forecast by sector, and the fuel requirements for power generation.

4.1 Energy Forecast by Source (2021–2030)

Historical energy consumption patterns reveal that fossil fuels remain the major source of energy in the country. However, recent developments and economic growth in the energy sector of Pakistan have certain impacts on energy consumption. The primary energy demand of the country has had a leading share of POL products and natural gas followed by coal, electricity, and LPG. Key results are as follows (see Table 5):

- Considering projected GDP growth, crude oil projections, population, and urbanization in the country, the primary energy demand is projected to reach 66.49 Mtoe in 2025 and 76.27 Mtoe by 2030 not including fossil fuels requirements for power generation and feedstock.
- The overall primary energy demand of the country is projected to reach 87.9 Mtoe in 2025 and 99.2 Mtoe by 2030, including fossil fuels requirements for power generation and feedstock.

- To meet the overall energy demand, the energy mix would consist of natural gas (including LNG) (34%), oil (28%), coal (23%), electricity (13%), and LPG (2%).
- The primary energy demand by 2030 is likely to remain similar to the historical pattern dominated by major consumption of natural gas (including LNG) followed by oil and coal in the country.

Table 5. Energy Forecast by Source (2021–2030)

Source	Primary Energy Demand (Mtoe) (Without Power generation and feedstock)				Primary Energy Demand (Mtoe) (With Power generation and feedstock)			
	2020	2021	2025	2030	2020	2021	2025	2030
Oil	18.13	19.67	22.97	26.78	19.6	21.1	24.0	27.5
Gas incl. LNG	17.78	16.73	18.17	19.50	30.4	28.5	30.6	33.7
LPG	1.27	1.35	1.60	1.96	1.27	1.35	1.60	1.96
Coal	10.61	11.23	12.70	14.93	15.0	15.6	20.6	22.9
Electricity	9.3	9.5	11.05	13.10	9.3	9.5	11.05	13.1
Total	**57.09**	**58.47**	**66.49**	**76.27**	**75.5**	**76.1**	**87.9**	**99.2**

Source: Economic Survey for Final Energy Consumption (2020)

In conclusion, the primary energy demand by fuel source is estimated to be as follows:

- Oil demand is likely to be 180 million barrels (24 Mtoe) in 2025 and 205 million barrels (27.5 Mtoe) in 2030 including oil-based power generation requirements.
- Likewise, the primary energy demand for natural gas (including LNG) is estimated at 1,431 TCF (30.6 Mtoe) in 2025 and 1,576 TCF (33.7 Mtoe) by 2030, including power generation and feedstock requirements.
- LPG is projected to require about 1.60 and 1.96 million tons per annum (Mtpa) in 2025 and 2030, respectively.
- The coal requirement is expected to be 27 Mtpa (20 Mtoe) in 2025 and 30 Mtpa (22.9 Mtoe) for the primary demand for industrial and power generation.
- The primary energy demand for electricity is predicted to be 149,235 GWh (28,300 MW) in 2025 and 176,940 GWh (33,600 MW).

4.2 Energy Forecast by Sector (2021–2030)

This section illustrates the energy demand forecast along with a detailed discussion of the historical pattern of energy consumption for all fuels and electricity. The results are estimated by each economic category—domestic, commercial, industrial, agriculture and transport sectors—on annual basis.

4.2.1 Domestic Sector

Historical trend

The domestic sector of Pakistan consumes mainly kerosene oil, natural gas, LPG, and electricity for cooking, heating, lighting, and electrical appliances. Some of the key observations based of review of the historical consumption pattern are as follows:

- Kerosene oil was reported as being the major source of fuel for cooking, heating, and conventional lighting purposes in the domestic sector of the country.
- With time, and because of the increased exploration for natural gas and its supply at a cheaper rate, the use of kerosene oil was significantly replaced by natural gas.
- Because of the substitution of natural gas and LPG for cooking and heating, the use of kerosene oil remains minimal and the share of natural gas and LPG increased during the period of review.
- Electricity consumption in the domestic sector kept increasing during the period because of increased rural electrification, the inclusion of modern electric appliances, and electricity being an efficient alternative fuel for domestic heating/cooling and cooking.

Forecast Results

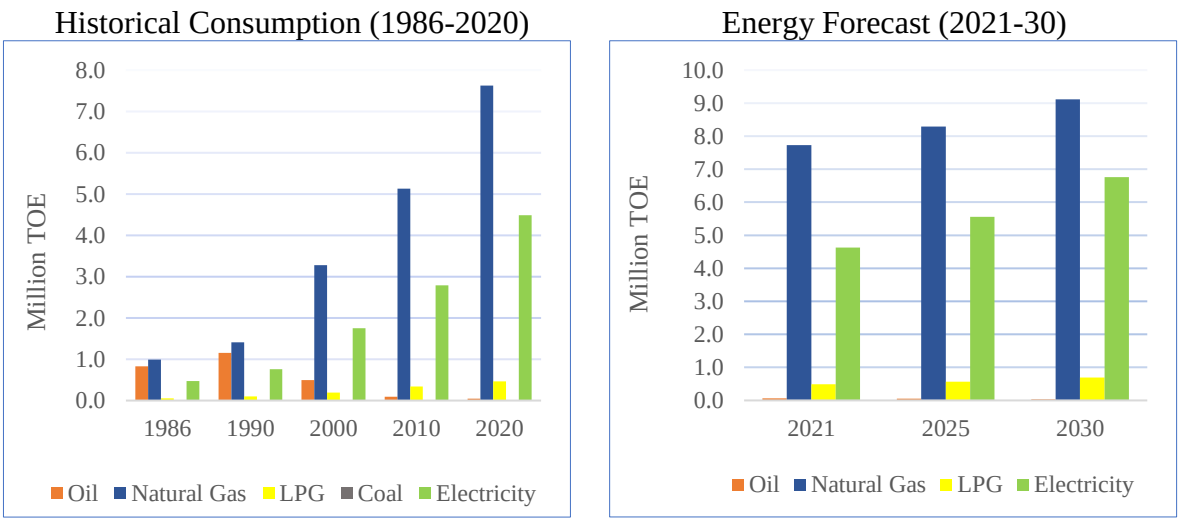


Figure 11. Energy Forecast for Domestic Sector (2021–2030) (Source: Economic Survey and Energy Year Book for Historical Consumption [1986–2020])

- With an increasing GDP per capita and the affordable price of natural gas and electricity by 2030, forecasting results follow the same increasing trends in natural gas and electricity consumption in the domestic sector.
- The resulting estimates indicate that by 2030, natural gas consumption (55%) will have a dominant share of the domestic sector, followed by electricity (40%) relative to overall energy consumption.

- Acknowledging the fast-depleting reserves of natural gas in Pakistan and the rapid advancement in modern heating/cooling and green cooking technologies, electricity may pave its way to replacing natural gas in the domestic sector in the future.

4.2.2 Commercial Sector

Historical Trend

In the past, the commercial sector of Pakistan has relied heavily on natural gas consumption, followed by electricity and LPG. Key remarks derived from reviewing the historical pattern are as follows:

- The use of natural gas in the commercial sector kept on increasing until natural gas supply priorities were changed by the government; as a result, LPG started replacing natural gas because of its ease of portability and comparable prices until 2010.
- Likewise, owing to the enormous use of electricity in the commercial sector (lighting, heating, cooling, commercial cooking, and small-scale production, etc.) and the non-availability of suitable alternate fuels, the consumption of electricity increased during the period of review.

Forecast Results

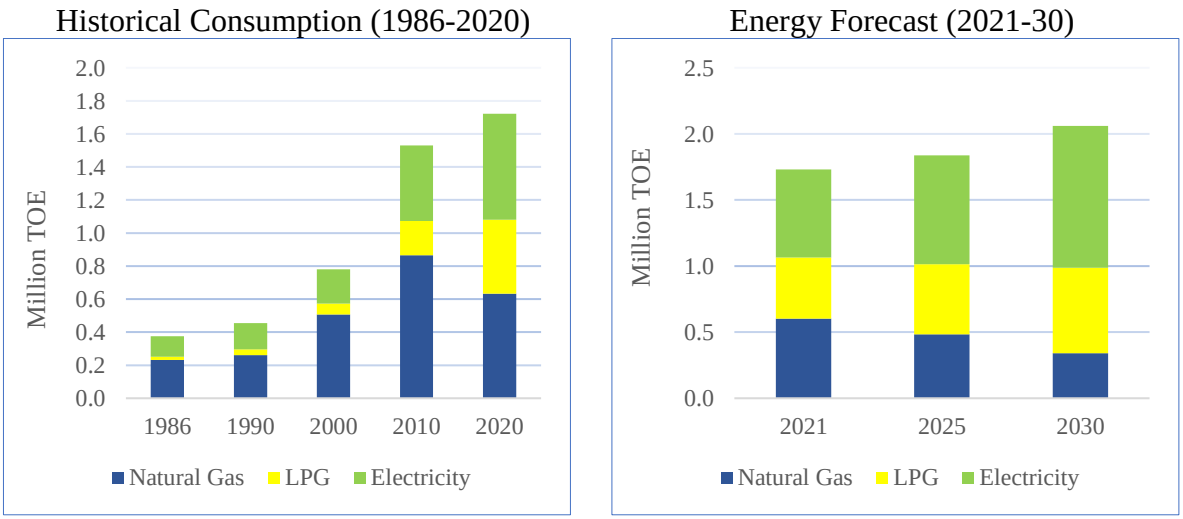


Figure 12. Energy Forecast for Commercial Sector (2021–2030) (Source: Economic Survey and Energy Year Book for Historical Consumption [1986–2020])

- The resulting estimates indicate the same consumption pattern for natural gas, LPG, and electricity for the commercial sector.
- The energy demand forecast by 2030 is likely to be dominated by electricity consumption (46%) followed by LPG (36%), whereas consumption of natural gas will be merely 19% in the overall consumption by the commercial sector.

- A continuous increase in LPG cylinder prices in the country may force a shift toward increased consumption of natural gas within the commercial sector of the country.

In addition, the importation of LNG supported by enhanced LNG storage facilities may substitute LPG consumption in the future.

4.2.3 Industrial Sector

Historical Trend

The industrial sector of Pakistan is one of the most energy-consuming of the economic sectors. It involves the use of large-scale industrial furnaces and burners, boilers, and heavy machinery to produce various products. Key historical consumption observations are listed below:

- In the past, industries have consumed mostly the natural gas as a primary fuel because of its prioritized supply and cheap flat rates.
- Petroleum products such as HSD, FO, kerosene oil, and coal were used as an alternate fuel, but because of the significant transportation cost associated with oil supply and difficult handling, consumption of POL products remained a fluctuating trend within the industrial sector.
- Coal mining enhancement, the advancement of coal-burning technologies (that enabled extraction of more heat due to the high carbon content present in coal), and the use of coal by-products by various industries, gradually increased the consumption of coal and replaced a fair portion of oil and natural gas consumption in the industrial sector.

Forecast Results

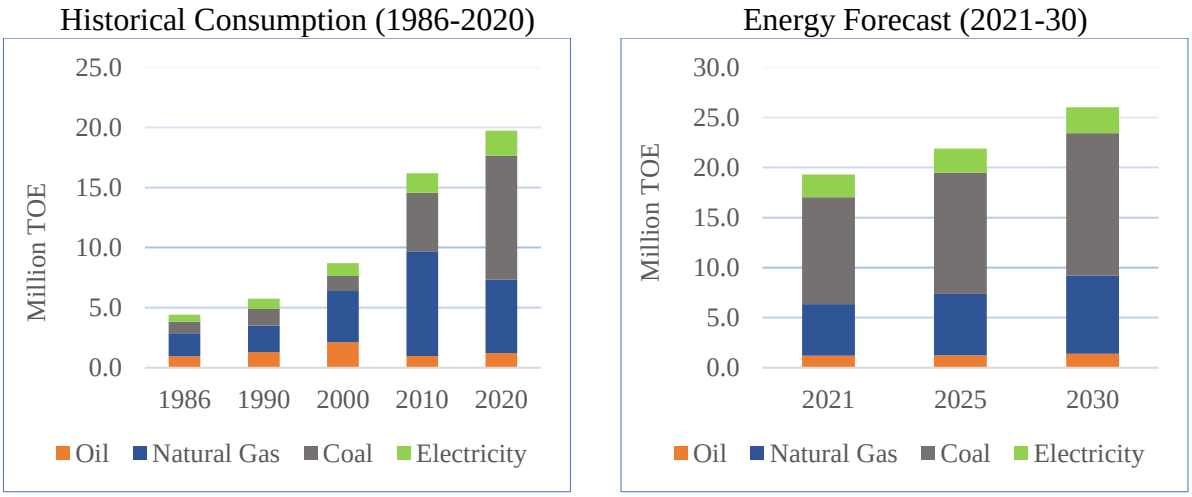


Figure 13. Energy Forecast for Industrial Sector (2021–2030) (Source: Economic Survey and Energy Year Book for Historical Consumption [1986–2020])

- The energy forecast for the industrial sector follows the linear consumption pattern and indicates the increased consumption of coal followed by natural gas and electricity.
- The resulting estimates based on industrial GDP growth and urbanization in the country show that by 2030 the consumption of coal in the industrial sector may follow an increasing trend and remain dominant with a 56% share followed by natural gas (28%) consumption.
- The consumption of electricity is expected to slightly increase over the years mainly because of its increased consumption by industry.
- The forecasted energy demand may vary in response to a policy measure for gas allocation for captive power generation, a shift of industry consumption from captive power to the national grid system, and a shift of gas consumption from the fertilizer sector to the power sector.

4.2.4 Agriculture Sector

Historical Trend

The agricultural sector plays a vital role in the socioeconomic development of the country. Historical consumption patterns for the agriculture sector in the country are reflected in the following list:

- In the last two and a-half decades, a conventional agricultural method based on internal combustion engines prevailed in the country, and POL products such as HSD and light diesel oil (LDO) served as the major sources of energy.
- The use of electricity in the sector increased because of multiple government-sponsored schemes (such as the provision of subsidized electric motors, pumps, etc.) to encourage farmers to adopt modern farming practices.
- In parallel, the advancement of electricity-based agricultural equipment, rural electrification, and provision of solar-powered stand-alone electricity supply solutions further served the purpose and recently, electricity has replaced a significant portion of POL consumption in the agricultural sector.

Forecast Results

- Considering the predicted GDP growth in the agriculture sector in the country by 2030, the forecasted results exhibit the same trend for electricity consumption for the agriculture sector. They indicate that electricity in the agricultural sector will be the main source of energy.
- The heavy reliance on electricity consumption may pose some operational challenges (e.g., distribution networks rehabilitation/expansion for provision of un-interrupted power supply for intensive crop production farming) to ensure the national food security of the country.
- The electricity consumption pattern in the agriculture sector indicates that farmers may tend toward solar tube-wells to meet their future demands and to avoid bills and uninterrupted

supply for smooth operation. However, this may lead to the over-extraction of groundwater in the country.[25]

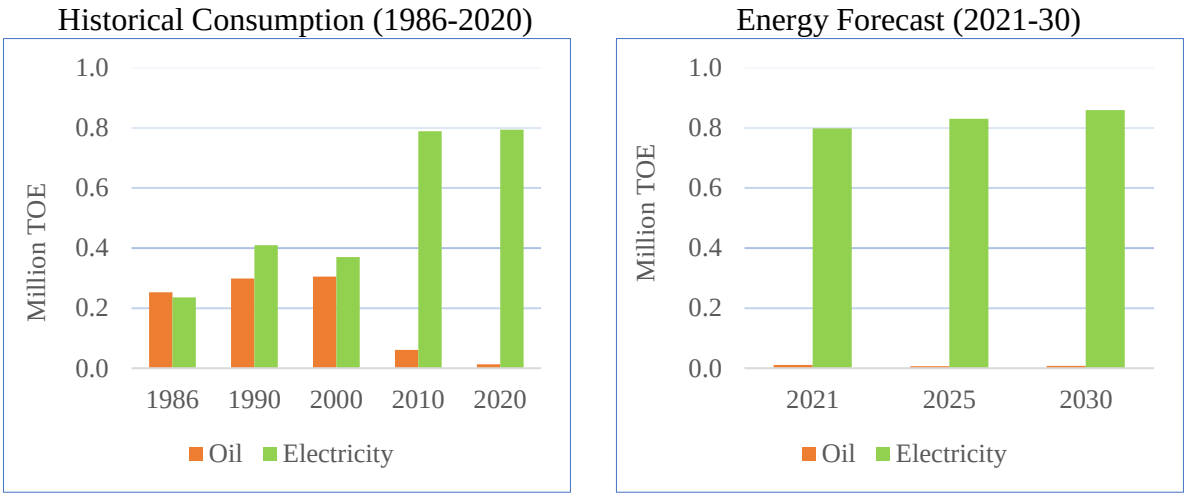


Figure 14. Energy Forecast for Agriculture Sector (2021–2030) (Source: Economic Survey and Energy Year Book for Historical Consumption [1986–2020])

4.2.5 Transportation Sector

Historical Trend

Since the last century, Internal Combustion Engine (ICE)-based transport has been used worldwide. Despite the associated low efficiency and environmental hazards, the world is dependent on the consumption of POL products for such means of transportation. Key observations from review of the historical consumption pattern for the transport sector are as follows:

- As in other under-developed countries, Pakistan also introduced CNG as an alternate fuel in early 1990 to replace a portion of POL product consumption.
- The aggressive demand for CNG in the transportation sector posed various issues related to the supply of natural gas to other sectors; therefore, the government reviewed the natural gas allocation policy,[26] and consequently, the consumption of CNG declined in the transportation sector.
- Nowadays, with the advent of electric vehicles, a paradigm shift may take place and in the future electricity consumption is expected to gradually start replacing POL products consumption.

Forecast Results

- Considering the continuous increase in vehicle transportation and the associated affordable prices and smooth supply, estimates for energy demand for the sector follow the same historical trend of POL products and CNG consumption in the transportation sector of the country.

- The forecasting results indicate that POL products will represent a major share of energy consumption in the sector and CNG likely will represent a minimal share of energy consumption in the future.
- Based on 2020 NEVP targets set to promote electric vehicle penetration, electricity is also considered the primary energy demand for the transportation sector.[27] However, the regression-based forecasting model does not capture the impacts of disruptive technologies like electric vehicles.

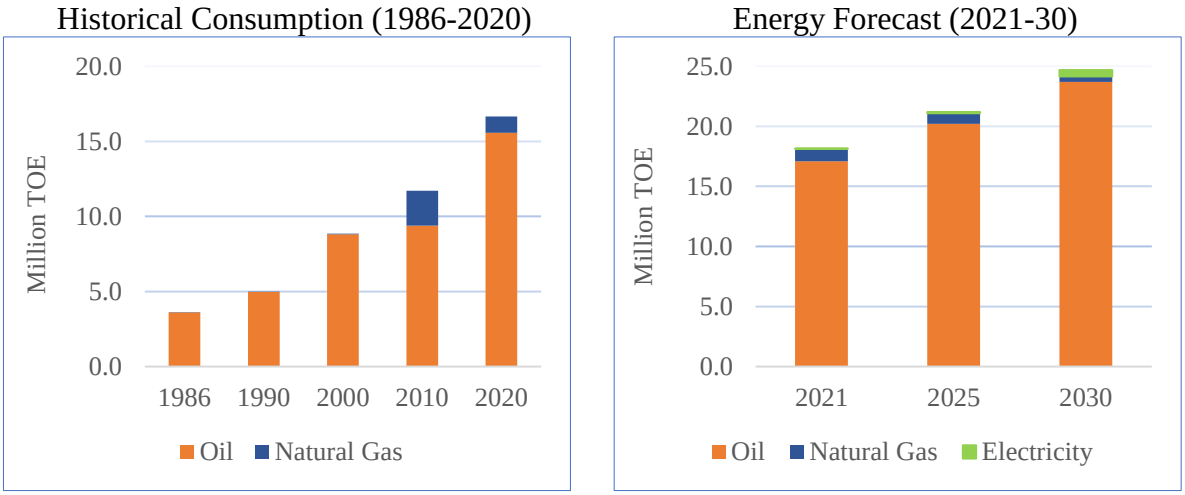


Figure 15. Energy Forecast for Transport Sector (2021–2030). Source: Economic Survey and Energy Year Book for Historical Consumption [1986–2020])

4.3 Fossil Fuel Requirements for Thermal Power Generation (2021–2030)

Historically, thermal power generation has been mainly dominated by furnace oil, followed by natural gas and diesel, but the government added coal-based power generation in recent years and decided to retire furnace oil-based power generation in the country. Estimates include additional plant capacity for thermal based power generation and retirement of thermal power plant for CPPA and KE obtained from IGCEP-2021 and the KE Generation Expansion Plan, respectively, for future thermal power generation.

The fuel requirement for thermal power generation is calculated based on the future thermal-based power generation in the country. Considering future generation plans by entities, the fossil fuel requirement for thermal power generation was calculated for 2021 to 2030 and key results are discussed below:

- As on 2020, the overall thermal based installed capacity of the country was 25,243MW generating 81,554 GWh power. The thermal based installed capacity of the country will reach up to 29,052MW by 2025 whereas 26,369 MW by 2030.

- The results show that future thermal power generation will mainly be based on coal- and gas-based power generation derived from imported LNG and natural gas.
- The CPPA system will largely depend on gas-based power generation derived from natural gas and imported LNG, followed by coal-based power generation for a thermal based power generation. Power generation based on furnace oil will be minimal in the CPPA system.
- KE is expected to depend on thermal power generation derived from natural gas and imported LNG, followed by coal and furnace oil generation.

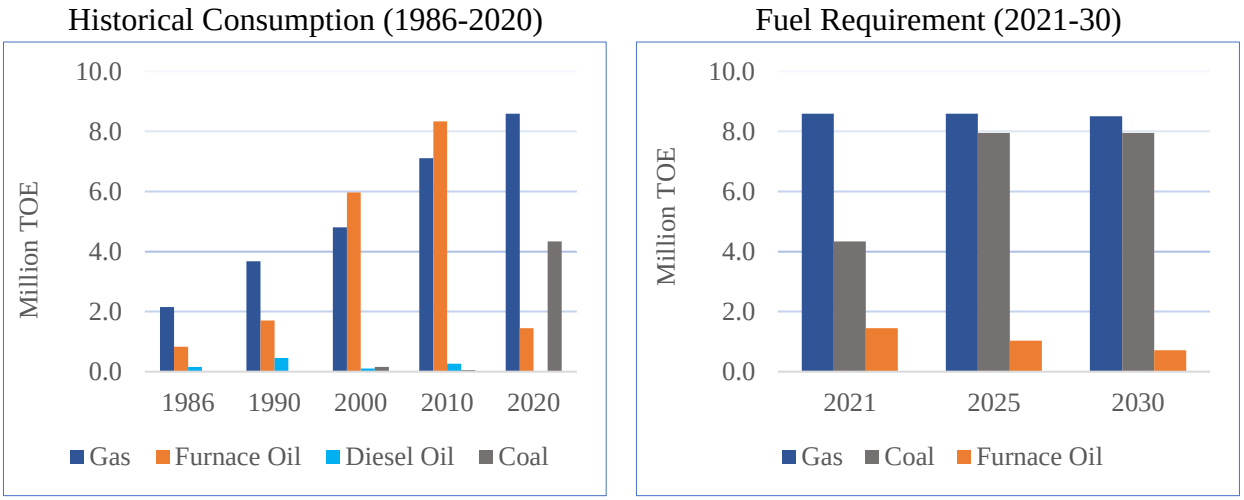
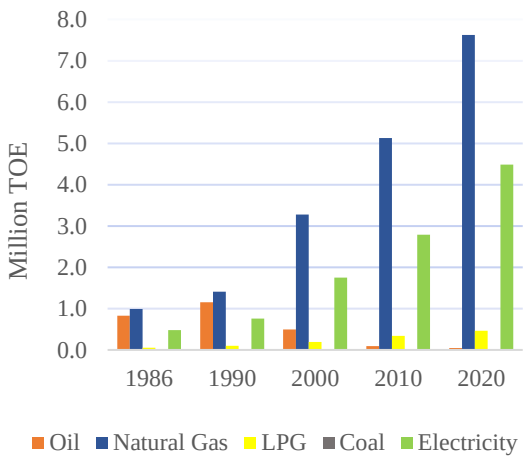


Figure 16. Fossils Fuel Requirement in Thermal Power Generation (2021–2030) (Source: State of Industry Report, IGCEP-2021 and K-Electric Future Plan)

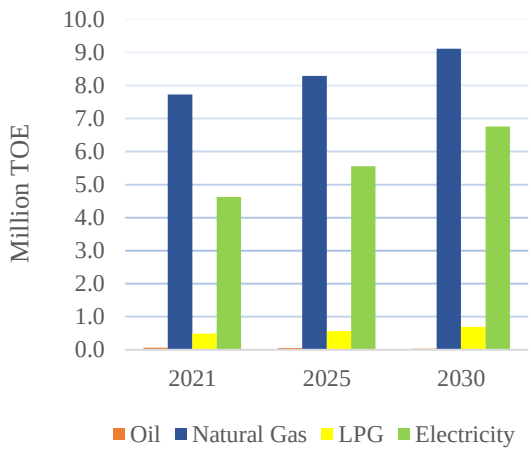
Overview of Results

Domestic Sector

Historical Consumption (1986-2020)

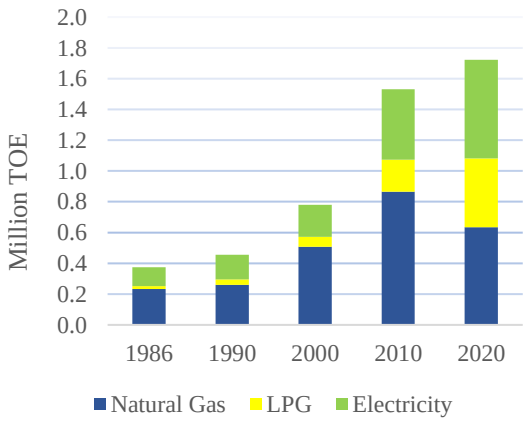


Energy Forecast (2021-30)

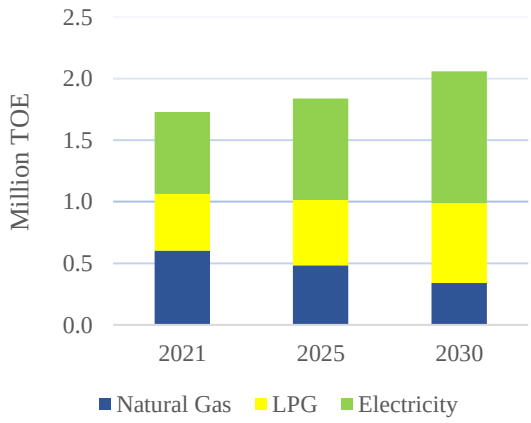


Commercial Sector

Historical Consumption (1986-2020)

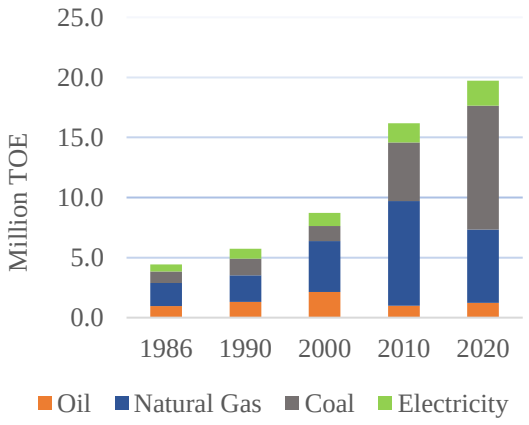


Energy Forecast (2021-30)

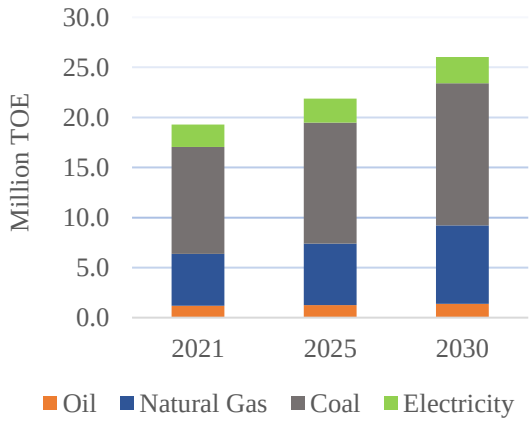


Industrial Sector

Historical Consumption (1986-2020)

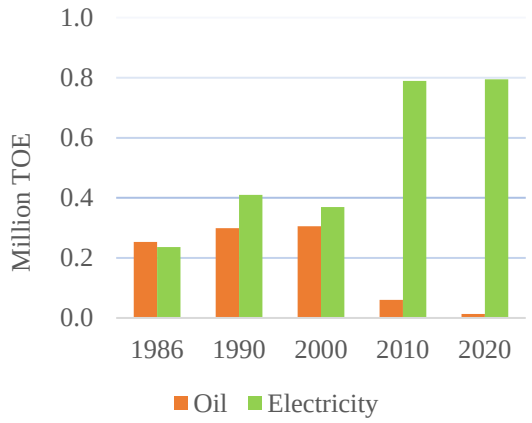


Energy Forecast (2021-30)

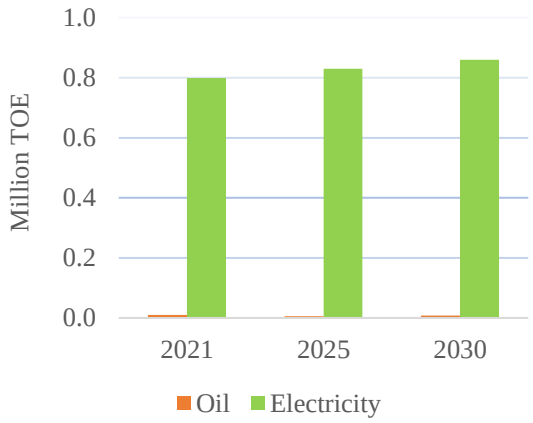


Agriculture Sector

Historical Consumption (1986-2020)

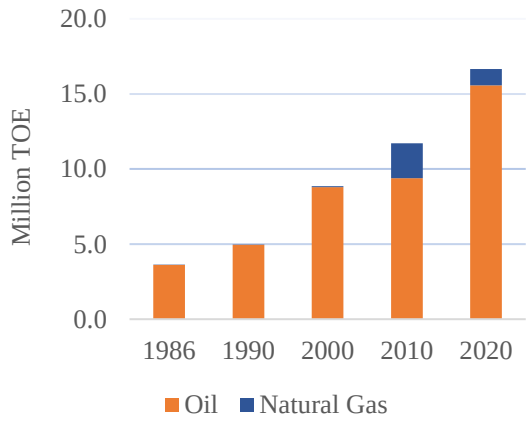


Energy Forecast (2021-30)

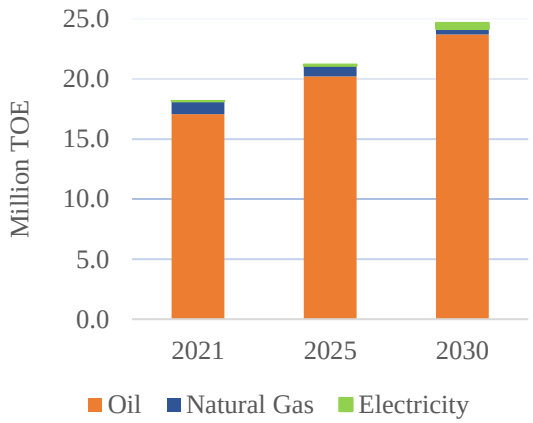


Transportation Sector

Historical Consumption (1986-2020)

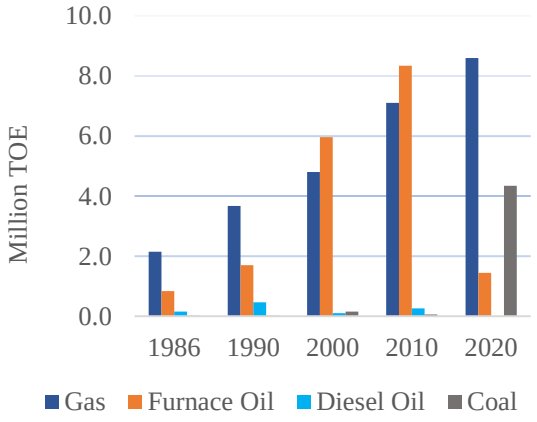


Energy Forecast (2021-30)

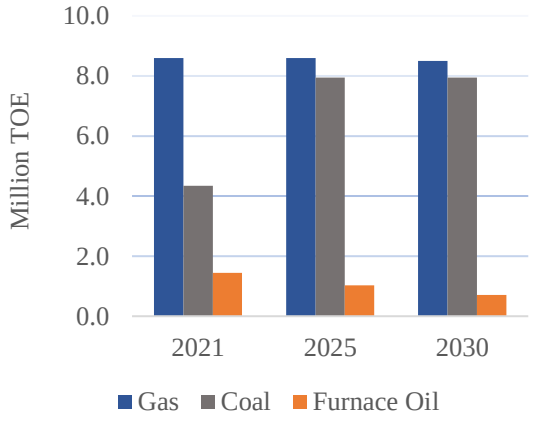


Fossil Fuel Requirements for Thermal Power Generation (2021–2030)

Historical Consumption (1986-2020)



Fuel Requirement (2021-30)



5. Limitations and Constraints

While performing an energy demand forecast, annual data results in annual results. If more granular seasonal projections are desired, monthly data would need to be used. Data limitations also exist regarding the lack of information about the disaggregation of energy consumption by purpose in several classifications of economic sectors. The above findings can be generalized for the entirety of the consumer categories by energy source on an annual basis. Seasonal data by the economic sector would be preferred for supporting policy recommendations.

Another limitation is associated with the selection of variables for the model estimates. Our demand model focused only on observed variables. There may be other explanatory variables other than real GDP growth, sector-wise energy tariffs, population, and urbanization that are not studied, but do influence the response variable. The model may include a variety of variables, including the following:

- A pattern of energy consumption for domestic consumers may vary between urban and rural populations, across income groups, types of households, and other key household characteristics.
- For nondomestic consumers, the use of modern technology in the industrial, commercial, agriculture, and transportation sectors may cause energy demand to increase more rapidly. Urban morphology, industrial structure, regulation context, climate condition, and resource endowment are also important variables for model estimates.
- Weather projections may also be critical for the seasonal variation in the demand forecast.

The selection of a forecasting model is mostly based on data availability, the objectives of the tool and planning exercise. Our demand model is based on multiple regressions with a time-series data set. Lastly, the limitation is related to our estimation strategy because OLS estimates only consider linear relationships, which may not be suitable for time-series data.[28] All methods exhibit a prediction error, but suitable models must yield the smallest mean absolute error as well as the smallest prediction bias. The least-squares regressions are not resistant to outliers. Therefore, reliance on an autoregressive model, such as auto-regressive moving average (ARMA), autoregressive integrated moving average (ARIMA), and vector autoregressive (VAR), for the smallest prediction bias in the result estimates is required.

6. The Way Forward and Recommendations

To improve energy demand forecasting, this section specifically discusses a pathway for IEP to address discrepancies, conflicts, and gaps in data, and underlying assumptions in the existing practices in the country. To develop improvements in demand forecasting methods and standardize historical data, IEP already started taking the following key steps:

- The formation of an energy database, with monthly consumption data, has already been started and the development of a mechanism to regularly update the data from all key energy sector stakeholders is under way. Disaggregation of energy consumption data by purpose will be dealt with during later stages.
- Forecasting shall be improved by adding some of the key variables such as income growth rate, energy intensity growth rate, weather (temperature, humidity, rain levels, etc.), consumer growth rate, household size, energy conservation, and device or appliance efficiency, industrial development, and calendar effects, etc., reflecting the consumption patterns of consumers.
- ARIMA will be used for energy forecasting to capture nonlinear relationships of time-series data sets to obtain the smallest prediction bias in the estimates of results. The forecasting methodology will also be improved by using a rolling time window instead of just forecasting all at once to see what, say, a five-year ahead model looks like compared to the data.

All relevant stakeholders including, concerned institutions, academia, and researchers, would be engaged in the demand estimation process and in achieving consensus for reliable projections.

An accurate and reliable IEP forecasting model can help transparently generate policy recommendations for the energy sector. Moreover, planning based on reliable energy forecast will provide balanced and affordable energy supply-and-demand management at different levels of energy planning ranges from short terms to long-term.

In future, an accurate and reliable IEP model will help to run multiple policy scenarios, such as natural gas depletion, Electric Vehicles penetration, shifting of industry from captive power plants towards national grid and reconfiguration of oil refineries. Such analyses will help to informed decision making in the energy sector.

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Unit Conversion

Source	Unit	TOE
Oil	1**Tonne**	1.04
Natural Gas	1**Million CFT**	23.392
LNG	1**Million CFT**	23.392
LPG	1**Tonne**	1.08
Local Coal	1**Tonne**	0.447
Imported Coal	**1 Tonne**	0.658
Electricity	1**GWh**	81.44

Source: Energy Year Book (2020)

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