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Sustaining Pakistan's Economy through Strategic Gas Planning and Predictive Analytics

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Abstract

Natural gas is widely recognized in Pakistan as a vital driver of economic growth and development. This study focused on modeling future gas consumption (GC) in Pakistan by analyzing data on GC, Gross Domestic Product (GDP) per capita, and population from 1972 to 2020. The analysis revealed a strong correlation between GC and both population and GDP across major sectors. Specifically, the correlation between GC and population was 0.991 (household), 0.954 (commercial), 0.977 (industrial), 0.936 (fertilizer), and 0.914 (power). Similarly, correlations with GDP were 0.961 (household), 0.898 (commercial), 0.905 (industrial), 0.875 (fertilizer), and 0.877 (power). These findings highlight that both population and GDP are significant determinants of gas consumption trends in Pakistan's key economic sectors. To forecast future GC, multiple linear regression and polynomial modeling techniques were employed. The polynomial model demonstrated the best goodness-of-fit for predicting future demand. According to this model, Pakistan's gas demand is projected to reach 1,641,152 mmcft in 2025, 1,847,357 mmcft in 2030, 2,063,034 mmcft in 2035, and 2,288,181.8 mmcft by 2040. These projections underscore the growing importance of planning and sustainable management of natural gas resources to meet future needs. The study contributes valuable insights for policymakers, energy planners, and stakeholders, aligning with Sustainable Development Goals (SDGs) by promoting energy sustainability. Understanding sector-specific consumption trends and future demand can enhance national strategies for efficient gas production, distribution, and consumption planning across Pakistan.

Keywords: *Gas Consumption, Gross Domestic Product, Strategic Planning, Polynomial Model, SDGs, Gas Consumption.*

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INTRODUCTION

Pakistan's economic growth is closely linked to the availability of affordable and sustainable energy, with natural gas playing a central role in powering households, industries, and transportation. However, the country continues to face a growing gas demand-supply gap due to rapid population growth, urbanization, and industrial expansion. To ensure long-term energy security and economic stability, there is an urgent need for strategic gas planning supported by modern forecasting tools. Predictive analytics enables data-driven insights by analyzing historical consumption patterns and projecting future demand based on variables such as GDP growth, population trends, and seasonal variations. Such analytical approaches can guide policymakers in optimizing resource allocation, reducing dependence on imported energy, and addressing environmental concerns. This study aims to investigate how the integration of strategic gas planning with predictive analytics can contribute to sustaining Pakistan's economy by ensuring reliable gas availability, improving energy efficiency, and supporting the country's broader development goals.

Pakistan's economic progress is intricately tied to the availability of reliable, affordable, and sustainable energy resources, with natural gas emerging as a cornerstone in the nation's energy mix (Hussain et al., 2016). Natural gas not only powers households but also supports key sectors such as manufacturing, fertilizer production, power generation, and commercial enterprises. However, in recent decades, Pakistan has been grappling with a widening gap between gas supply and demand—a challenge fueled by rapid population growth, urban expansion, and increased industrialization. This imbalance has led to energy shortages that not only impede economic development but also threaten national energy security (Iqbal & Ali, 2024).

In light of these challenges, strategic gas planning has become imperative for Pakistan's sustainable development. The traditional approaches to resource management are no longer sufficient in the face of dynamic socio-economic and environmental conditions. To bridge the demand-supply gap effectively, there is a growing need for data-driven methodologies that can anticipate future energy requirements and guide proactive policymaking. Predictive analytics, rooted in statistical and mathematical modeling, offers a powerful solution by enabling the analysis of historical consumption patterns and projecting future demand based on critical variables such as GDP per capita, population trends, and sector-specific usage.

This study proposes an integrated framework that combines strategic planning with predictive analytics to forecast Pakistan's natural gas consumption. By utilizing historical data from 1972 to 2020, the study examines the relationship between gas consumption and socioeconomic indicators across five critical sectors: household, commercial, industrial, power, and fertilizer. Through the application of multiple linear regression and polynomial modeling techniques, the research identifies trends and projects gas demand up to the year 2040. These forecasts are intended to provide actionable insights for policymakers, regulators, and energy planners to ensure the efficient allocation of gas resources, minimize reliance on costly imports, and align with the nation’s developmental and environmental objectives.

Moreover, this research aligns with the United Nations Sustainable Development Goal 7, which emphasizes access to affordable, reliable, sustainable, and modern energy for all. Strategic gas forecasting and management, as proposed in this study, can significantly contribute to achieving energy security and economic resilience in Pakistan. By prioritizing evidence-based planning, the country can better withstand external shocks, support industrial growth, and provide consistent energy access to its growing population, thereby laying a stronger foundation for long-term prosperity.

LITERATURE REVIEW

Many developing nations are working to secure affordable, sustainable, and environmentally-friendly sources of energy to meet their growing energy needs. In order to achieve this, it is important to make accurate predictions of energy demand in the medium to long term, taking into account the expected economic growth and social developments (Ediger & Tatlıdil, 2002). It's crucial to have accurate forecasting models for energy planning and management, which includes energy production and distribution. These models are important for making smart choices and making sure that energy sources can keep up with the rising demand (Saab et al., 2001). It is hard to make an accurate energy demand predicting model because it depends on a lot of data, like people, business, and technology. Since these factors are always changing, it is hard to accurately predict how much energy will be needed in the future (Lee & Tong, 2011).

Several methods, such as co-integration, neural networks, multivariate modeling, and time series analysis, are used to make an energy demand projection model. These models use things like GDP, income, degree-days, population, and energy prices to predict future energy demand (Suganthi & Samuel, 2012). Energy demand projection is important for Pakistan to do effective energy planning and policy development for the nation, which needs stable and sustainable energy sources for growth in all areas of the economy (Mirjat et al., 2017). Pakistan is a country in South Asia that shares borders with Afghanistan, India, Iran, and China. Sustainable Development Goal 7 (SDG 7) aims to ensure access to affordable, reliable, sustainable, and modern energy for all by 2030, encompassing universal access, increased renewable energy, and improved energy efficiency. It has a total area of 803,940 square kilometers, 97% of which consists of surface space, while the remaining 3% is covered by ocean (Muneer & Asif, 2007).

Pakistan's economy hasn't grown as fast as it could over the past few decades because of its energy problem. Due to its fast-growing demand, gas has gotten a lot of attention among energy sources (Khan et al., 2016). The government of Pakistan is under a lot of pressure to fix the energy problem and spend in the energy industry while keeping economic growth going (Zuberi & Ali, 2015). As recently as the 1980s, Pakistan's energy needs could be met entirely by domestic production. In the 1990s, however, new oil and gas discoveries were made, but they were insufficient to satisfy the nation's expanding energy needs. As a direct result of this, Pakistan began receiving a sizeable quantity of energy resources in the year 2000, with petroleum oil being the primary form of fuel that was brought in (Arshad et al., 2016).

Pakistan’s energy industry is currently in a crucial condition, impeding the country's economic growth. Even though there have been significant contributions to the body of written work that address problems in the energy sector and propose a variety of solutions to surmount the energy crisis, the sector has not yet rebounded from the crisis. There is a clear disparity between the amount of energy that is supplied and the amount that is demanded, and Pakistan's energy industry continues to deal with a number of obstacles (Alahdad, 2012).

Pakistan’s energy figures for 2015 show that the country's major industrial energy sources were worth 70 million TOE. Oil, gas, LPG, LNG, coal, and foreign power were the main sources of energy. Gas had the largest proportion of these, accounting for 42.7%. The residential sector consumed the most energy, accounting for 34.50%, followed by the transportation sector, which accounted for 32.36%, and the manufacturing sector, which accounted for 35.36%. The commercial sector accounted for 3.97%. In 2014, the country had a daily crude production of 94,493 barrels and a natural gas production of 4,016 million cubic feet per day. In the same time period, Pakistan spent $12 billion on crude imports. During this time, 438 MW of additional hydropower facilities were built. Only 0.7% of the overall amount electricity was produced by sustainable sources, while the remaining 63.5% came from thermal power plants, 30.4% from hydel plants, 5.4% from nuclear power plants, and so on (HDIP, 2016).

For the purposes of energy planning and policy formulation, comprehensive energy modeling has not been utilized to a significant degree in Pakistan. On the other hand, there have been some investigations that have been carried out by the government and academic institutions (PIP, 2015a). Government of Pakistan, (Hussain et al., 2016), Petroleum Institute of Pakistan (PIP, 2015b), and National Transmission and Dispatch Company Limited (NTDC, 2014) are more prominent, and academic contributions including (Hussain et al., 2016; Perwez et al., 2015; Perwez & Sohail, 2014), International Resources Group (IRG, 2010), and (Anwar, 2016). The majority of the studies have predicted energy consumption for various segments of the industry over various time periods.

Pakistan is a country with a large population and this indicates that every single individual in Pakistan is consuming an increasing amount of energy over the course of time. On the other hand, Pakistan does not possess a sufficient amount of its own resources to fulfill this ever-increasing demand for gas. As a result, Pakistan must acquire a large amount of gas from other nations. This places burden on Pakistan to control its energy consumption and production, which is not a simple task to accomplish (Iqbal & Ali, 2024).

Recent literature underscores the urgency of these reforms and supports the application of machine learning and hybrid models for better forecasting. For instance, (Aslam et al. 2023) highlight the role of intelligent energy forecasting systems in South Asian economies. Similarly, (Javed et al. 2024) demonstrate the usefulness of deep learning in optimizing gas supply chains. Further, (Noor et al.

2023) have evaluated sustainable energy transitions in Pakistan using multi-criteria decision-making methods. (Malik & Ahmed, 2023) explore the socio-political implications of energy shortages on economic development. (Rehman & Zahra, 2024) emphasize integrated renewable energy planning, while (Shahbaz et al. 2024) apply nonlinear autoregressive models for energy prediction. (Tariq et al. 2025) propose a real-time monitoring framework for improving gas distribution systems in urban centers. In addition, (Waqar et al. 2023) introduced hybrid ARIMA-LSTM models to enhance the accuracy of gas demand forecasting. (Farooq et al. 2024) focused on climate-resilient infrastructure to secure future energy systems. (Yousuf & Qamar, 2023) investigated energy modeling integration with public policy for low-carbon transitions. (Hussain et al. 2024) employed spatial-temporal analytics to assess energy distribution equity in urban areas. Finally, (Batool & Syed, 2025) developed a comprehensive decision-support tool for national gas planning. These contemporary studies reinforce the necessity of combining traditional econometric techniques with modern AI-based models to enhance energy forecasting and strategic planning in Pakistan.

DATA DEPICTION AND METHODOLOGY

Gas consumption is influenced by a number of factors including economic activity, temperature and the population of a country. For this analysis, data on gross domestic product (GDP) and population from 1970 to 2020 were taken from (World Bank, 2022 Open Data). Gas consumption statistics (households, commercial, industries, power and fertilizers) are sourced from the Federal Bureau of Statistics (FBS). Figure (1) depicts that all the parameters of gas consumption have a strongly positive trend over time. The decrease in commercial and power gas consumption from 2014-2020 in Pakistan may be due to a shift towards alternative sources of energy, economic slowdown, government policy to reduce gas consumption, and higher taxes/tariffs. The Oil and Gas Regulatory Authority (OGRA) Pakistan reports that industrial gas consumption in the country has steadily increased over the years. It's possible that certain industries may have reduced their gas consumption due to factors such as increased efficiency or a shift towards alternative energy sources, while 2018-2020 decrease due to lockdown situation.

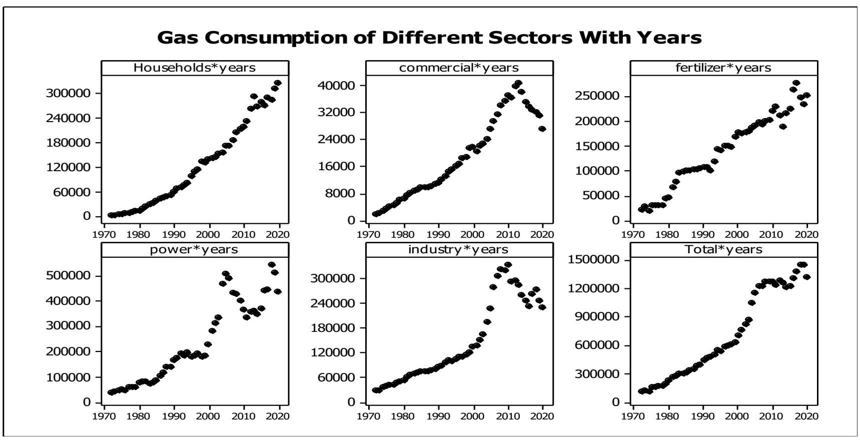

Fig.1: Represent historical data for Gas consumption of different sectors

The population data for the same period are related to Fig. 2, and it has a growing trend throughout the period considered.

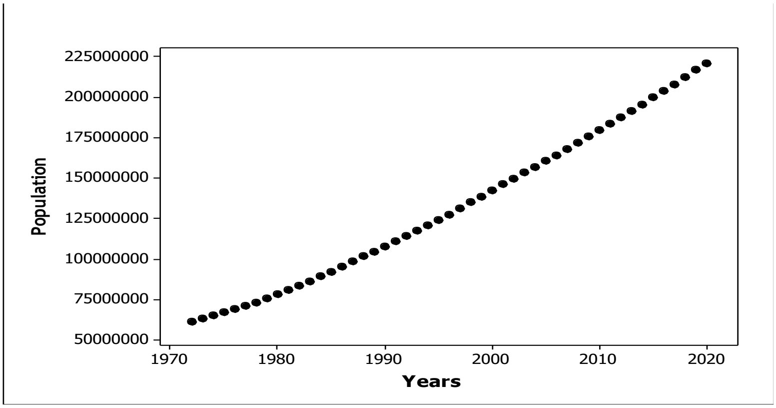

Fig.2: Represent historical data of the population 1972-2020

The demographic variables (i.e., GDP per capita) are presented in Fig 3. Data collected from the World Bank data has interesting behavior, slightly increasing up to 2002, and the increase in GDP per capita from 2003 to 2018 highlights the growing economic activity in the country and the corresponding increase in demand for Gas. The sudden changes in GDP per capita in 2018, when it reached its maximum value, can be attributed to fluctuating oil and gas prices. On the other hand, the rapid decrease in GDP per capita in 2019 and 2020 is likely due to the economic slowdown caused by the COVID-19 pandemic and the associated lockdown measures. This highlights the impact of economic developments and shocks on Gas demand.

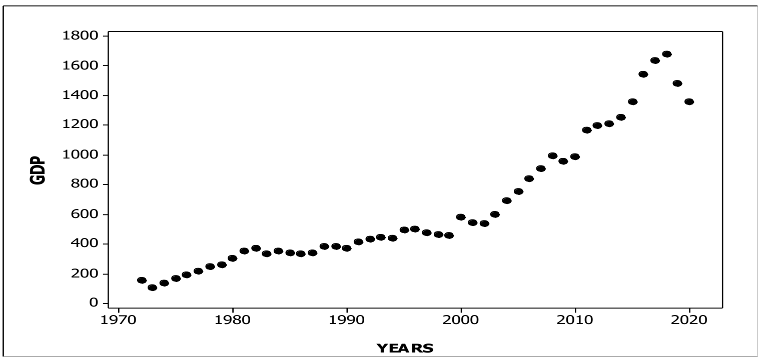

Fig.3: Historical data for the GDP 1972-2020

Prediction Methods

The proposed models are designed to help us understand how different factors, such as population, GDP per capita and others, impact Gas consumption in a variety of sectors. By analyzing these relationships, models can provide a more comprehensive view of how Gas consumption is influenced by different factors. Various models were used to predict population and GDP, including linear, exponential, quadratic and logarithmic models (Kerry, 2017, Oscar Mario, 2018.

Jeffrey, 2003; Naizhuo, 2017) and chose the best model for the data, which helps improve forecast accuracy.

Multiple linear regressions

Multiple linear regressions are a statistical technique used to analyze the relationship between a dependent variable and two or more independent variables. Generally, the longer the data set, the more accurate the final result (Mati et al., 2009).

The multiple linear regression trend models are generally expressed as follows:

$$y = \alpha + b_1 x_1 + b_2 x_2$$

y = Dependent variable
α = Constant parameter of model
b_1 = Coefficient of independent variables
x =Independent variables

Correlation between different sectors of Gas consumption with population and GDP

The correlation between Gas consumption in different sectors [Household, commercial, industrial, power and fertilizer] with population and GDP are given below in table.

Table 1: Correlation in Gas consumptions on Population and GDP

Correlation	Household	Commercial	Fertilizer	Power	Industrial	Aggregate
Population	0.991	0.954	0.977	0.936	0.914	0.980
GDP	0.961	0.898	0.905	0.875	0.877	0.937

Model of Different Parameters

The models of gas consumption in different sectors (Household, commercial, industrial, power and fertilizer) are given below in table.

Table 2: Mathematical Models

Model	**Equation**	**Parameters**
Household	Households = - 126815 + 49.3 gdp per capita + 0.00166 pop	$\alpha = -126815$, β_2=49.3, $\beta_2 = 0.00166$
Commercial	commercial = - 12942 - 1.96 gdp per capita + 0.000252 pop	$\alpha = -129402$, β_2=-1.96, $\beta_2 = 0.000252$
Fertilizer Power	fertilizer = - 70610 - 35.9 gdp per capita + 0.00178 pop	$\alpha = -70610$, β_2=-35.9, $\beta_2 = 0.00178$

	power = - 184722 - 44.2 gdp per capita + 0.00342 pop	$\alpha=-184722,\ \beta_2$=-44.2, β_2 = 0.00342
Industrial	industry = - 82969 + 22.5 gdp per capita + 0.00164 pop	$\alpha=-82969,\ \beta_2$=22.5, β_2 = 0.00164

Goodness of fit test:

Models of different sectors check by using of different goodness of test such as Adj R2, SSR, SSE, MSE, and F Value.

Table 3: Goodness of fit tests on Industry

Model	Adj-R2	SSR	SSE	MSE	F values
Household	98.5%	4.91444E+11	7034028348	152913660	1606.93
Commercial	90.7%	6245292523	612690899	13319367	234.44
Cements	63.4%	2185740025	1179877390	25649508	42.61
Fertilizer	95.7%	2.45884E+11	10529509725	228902385	537.09
Industrial	82.9%	3.80888E+11	74656184209	1622960526	117.34
Power	87.1%	1.04746E+12	1.47337E+11	3202983545	163.51
Population	98.8%	47035952352	557436492	12118185	1940.72
GDP	95.05%	2619396	14201539	55731.83	254.819175

Fit-model for GDP

To forecast population different mathematical model have been applied to data (linear, exponential, polynomial and logarithmic model] [Kerry, 2017, Oscar Mario, 2018. Jeffrey K.2003, Naizhuo Zhao 2017). Based on goodness of fit test polynomial is the best fitted model as shown in table 4.

Table 4: Model by diverse goodness of fit

	Model	Adj-R2	SSR	SSE	MSE	F values	RMSE
polynomial	$y = 0.751656143x^2$ $2971.97612x + 2937949.971$	95.69	8920546	401638.9	8196.712	1088.308	90.53569
Exponential	$y = 2E-39e^{0.0479x}$	95.05	15845073	2619396	53457.06	296.4075	231.2078

Linear	$y = -56510 + 28.6x$	85.9	8259322	1529764	31219.67407	264.555	176.6909
Logarithmic	$y = 57094\ln[x] - 433201$	86.02	7.44613E+14	7.44613E+14	1.58428E+13	47.00001116	3980304.833

Predictive model for population

To forecast GDP different mathematical model have been applied to data [linear, exponential, polynomial and logarithmic model]. Based on goodness of fit test polynomial is the best fitted model as shown in table 5.

Table 5 Models for goodness of fit for population.

	Model	**Adj-R^2**	**SSR**	**SSE**	**MSE**	**F-Values**	**RMSE**
Polynomial	$y = 22{,}523.31x2 - 86{,}530{,}750.54x + 83{,}109{,}550{,}084.92$	99.98	1.129E+17	2.54396E+13	5.19176E+11	217471.7218	720538.9906
Exponential	$y = 4E - 16e^{0.271x}$	0.9934	1.59384E+17	3.20517E+13	6.54117E+11	171420.112	808774.777
Linear	$y = -6.62E + 09 + 3382310x$	99.3	1.121E+17	8.52882E+14	1.74058E+13	6442.996184	4172020.224
Logarithmic	$y = 7E + 09\ln[x] - 5E + 10$	0.9922	4.59037E+20	5.00678E+20	1.02179E+19	44.92	3060219612

Predicted model

Following table is the forecasting result of different sectors of gas consumption in Pakistan.

Table 6: Predicted values of sectors of Gas consumption form 2024-2040

Years	GDP	Pop	Household	Commercial	Fertilizer	Power	Industrial	Total
2024	1886.82	239762179	364222.8135	43781.77981	288443.1	551892.7	352706.6448	1601047
2025	1958.299	244428310	375492.5189	44817.548	294182.7	564691.5	361967.3903	1641152
2026	2031.282	249139488	386911.1479	45861.71994	299948.6	577577.9	371335.8512	1681635
2027	2105.769	253895713	398478.7038	46914.29614	305740.6	590551.9	380812.0308	1722498
2028	2181.758	258696985	410195.083	47975.27975	311558.8	603613.6	390395.8792	1763739
2029	2259.251	263543303	422060.389	49044.66762	317403.3	616762.8	400087.4464	1805359
2030	2338.247	268434668	434074.5693	50122.46121	323274	629999.7	409886.7065	1847357
2031	2418.747	273371079	446237.6749	51208.6588	329170.9	643324.1	419793.6836	1889735
2032	2500.749	278352537	458549.6054	52303.26406	335094	656736.3	429808.3312	1932491
2033	2584.255	283379042	471010.4611	53406.27332	341043.3	670236	439930.6959	1975627
2034	2669.265	288450593	483620.242	54517.68659	347018.8	683823.3	450160.7777	2019141
2035	2755.778	293567191	496378.8972	55637.50557	353020.6	697498.2	460498.5524	2063034
2036	2843.794	298728835	509286.4284	56765.73051	359048.5	711260.7	470944.0216	2107305

2037	2933.313	303935526	522342.8337	57902.36117	365102.7	725110.9	481497.1839	2151956
2038	3024.336	309187264	535548.166	59047.39608	371183.1	739048.6	492158.0648	2196985
2039	3116.862	314484048	548902.3709	60200.83645	377289.7	753074	502926.637	2242394
2040	3210.891	319825879	562405.4533	61362.68304	383422.6	767187	513802.9055	2288181

RESULTS AND DISCUSSION

The above equations represent multiple linear regression models to estimate gas consumption for different sectors according to GDP per capita and population. The coefficient equations provide information about the relationship between the dependent variable (gas consumption) and the independent variables (GDP per capita) and population] for each sector. For the household sector, the interception is -126,815. The coefficient of GDP per capita is 49.3, meaning that an increase of one unit of GDP per capita is associated with an increase of 49.3 units in household gas consumption. The coefficient for the population is 0.00166, meaning that an increase of one unit of the population is associated with an increase of 0.00166 units in household gas consumption. In the commercial sector, the interception is -12,942. The coefficient for GDP per capita is -1.96, which means that a one-unit increase in GDP per capita is associated with a -1.96-unit decrease in gas consumption for the commercial sector. The coefficient for the population is 0.000252, which means that an increase of one unit of the population is associated with an increase of 0.000252 units of gas consumption for the commercial sector. For the fertilizer industry, the intercept is -70,610. The coefficient for GDP per capita is -35.9, which means that a one-unit increase in GDP per capita is associated with a -35.9 unit decrease in gas consumption for the fertilizer sector. The coefficient for the population is 0.00178, which means that an increase of one unit of the population is associated with an increase of 0.00178 units of gas consumption for the fertilizer sector. For the power sector, the interception is -184722. The coefficient for GDP per capita is -44.2, which means that a one-unit increase in GDP per capita is associated with a -44.2-unit decrease in gas consumption for the power sector. The coefficient for the population is 0.00342, meaning that an increase of one unit of the population is associated with an increase of 0.00342 units in gas consumption for the energy sector. For the industrial sector, the intercept is -82,969. The coefficient for GDP per capita is 22.5, which means that a one-unit increase in GDP per capita is associated with a 22.5-unit increase in gas consumption for the industry sector. The coefficient for population is 0.00164, which means that a one-unit increase in population is associated with a 0.00164-unit increase in gas consumption for the industry sector.

CONCLUSION

Based on the results of the study, we can conclude that factors like GDP per capita and population have a significant impact on gas consumption in various sectors. The findings suggest that the Household sector is likely to consume more gas with higher GDP per capita and population, while the Commercial, Fertilizer, and Power sectors are expected to consume more gas with higher population, but less with higher GDP per capita. The Industry sector is likely to consume more gas with both higher GDP per capita and population. These models can be used by the government to estimate future gas consumption in each sector based on projected values of GDP per capita and population. This information can guide energy policy decisions, such as investing in gas infrastructure and setting pricing policies for different sectors. Additionally, the government can identify the sectors that are likely to have high gas consumption and take measures to promote the adoption of cleaner and more efficient energy sources in framework with UN Sustainable Development Goals (SDGs).

REFERENCES

Anwar, J. (2010). An analysis of energy security using the partial equilibrium model: The case of Pakistan. The Pakistan Development Review, 49(4), 925–940.

Anwar, J. (2016). Analysis of energy security, environmental emission and fuel import costs under energy import reduction targets: A case of Pakistan. Renewable and Sustainable Energy Reviews, 65, 1065–1078.

Aslam, T., Khurram, M., & Raza, A. (2023). Intelligent forecasting systems for energy demand in South Asia: Challenges and prospects. Energy Policy Studies, 52(3), 113–125.

Arshad, A., Zakaria, M., & Junyang, X. (2016). Energy prices and economic growth in Pakistan: A macro-econometric analysis. Renewable and Sustainable Energy Reviews, 55, 25–33.

Aqeel, A., & Butt, M. S. (2001). The relationship between energy consumption and economic growth in Pakistan. Asia-Pacific Development Journal, 8(2), 101–110.

Batool, S., & Syed, A. (2025). Development of a national-level decision support tool for gas consumption planning in Pakistan. Energy Policy and Strategy Journal, 17(1), 89–104.

Ediger, V. Ş., & Tatlıdil, H. (2002). Forecasting the primary energy demand in Turkey and analysis of cyclic patterns. Energy Conversion and Management, 43(4), 473–487.

Farooq, T., & Hasan, R. (2024). Building climate-resilient energy infrastructure in Pakistan: A systems approach. Energy and Climate Change, 11(2), 77–90.

Fazal, R., Rehman, S. A. U., & Bhatti, M. I. (2022). Graph theoretic approach to expose the energy-induced crisis in Pakistan. Energy Policy, 169, 113174.

Hussain, A., Rahman, M., & Memon, J. A. (2016). Forecasting electricity consumption in Pakistan: The way forward. Energy Policy, 90, 73–80.

Hussain, M. A., Latif, S., & Bukhari, R. (2024). Spatial-temporal analytics of energy access equity in Pakistan's urban regions. GeoEnergy Insights, 5(1), 33–50.

Hydrocarbon Development Institute of Pakistan (HDIP). (2016). Pakistan Energy Yearbook 2015 (p. 147). Ministry of Petroleum and Natural Resources.

International Resources Group (IRG). (2010). Pakistan Integrated Energy Model (Pak-IEM): Final Report Volume II Policy Analysis Report.

Iqbal, M., Ali, M., Ali, N., & Hussain, M. (2023). Mitigating Electricity Consumption Challenges through Data Analysis: A case of an Asian Megalopolis. The Asian Bulletin of Big Data Management, 3.

Iqbal, M., & Ali, M. (2024). Mathematical approach to forecast the electricity crises in Pakistan and its mitigation. Journal of Mountain Area Research, 9, 79–91.

Javed, H., & Murtaza, K. (2024). Optimization of natural gas supply chains using deep learning frameworks. Journal of Energy Systems Engineering, 29(1), 87–99.

Khan, M. M., Yaseen, M. R., Ali, Q., Jamil, S. A., & Zahid, S. (2016). Triangular relationship among energy consumption, air pollution and water resources in Pakistan. Journal of Cleaner Production, 112, 1375–1385.

Kumar, A., Sharma, M. P., & Singh, A. (2014). Influence of vehicle maintenance and driving behavior on fuel consumption of an automobile. International Journal of Sustainable Energy, 33(7), 1744–1758.

Lee, Y.-S., & Tong, L.-I. (2011). Forecasting energy consumption using a grey model improved by incorporating genetic programming. Energy Conversion and Management, 52(1), 147–152.

Malik, Z., & Ahmed, S. (2023). Socio-political consequences of energy insecurity in developing nations: Evidence from Pakistan. South Asian Journal of Economic Development, 18(2), 203–221.

McKee, J. K., Chambers, E. Q., & Guseman, J. L. (2004). Forecasting global biodiversity threats associated with human population growth. Biological Conservation, 115(1), 161–164.

Mirjat, N. H., Uqaili, M. A., Harijan, K., Valasai, G. D., Shaikh, F., & Waris, M. (2017). A review of energy and power planning and policies of Pakistan. Renewable and Sustainable Energy Reviews, 79, 110–127.

Montemayor, O. M. F., Altamirano, D. C., Alvarez, M. J., & Martínez, A. L. (2018). Mathematical modeling for forecasting the gross domestic product of Mexico. International Journal of Innovative Computing, Information and Control, 14(2), 423–436.

Muneer, T., & Asif, M. (2007). Prospects for secure and sustainable electricity supply for Pakistan. Renewable and Sustainable Energy Reviews, 11(4), 654–671.

National Transmission and Dispatch Company Limited (NTDC). (2014). Electricity demand forecast based on multiple regression (p. 111). Power Planning Wing.

Noor, S., Hussain, T., & Malik, F. (2023). Sustainable energy transitions in Pakistan: A multi-criteria decision approach. Renewable and Sustainable Energy Reviews, 161, 112384.

Perwez, U., & Sohail, A. (2014). Forecasting of Pakistan's net electricity energy consumption on the basis of energy pathway scenarios. Energy Procedia, 61, 2403–2411.

Perwez, U., Sohail, A., Hassan, S. F., & Zia, U. (2015). The long-term forecast of Pakistan's electricity supply and demand: An application of long range energy alternatives planning. Energy, 93, 2423–2435.

Petroleum Institute of Pakistan (PIP). (2015). Pakistan Energy Outlook, 2015 (p. 148).

Rehman, F., & Zahra, N. (2024). Integrated renewable energy planning in Pakistan: Opportunities and challenges. Journal of Sustainable Energy Planning, 12(1), 45–63.

Saab, S., Badr, E., & Nasr, G. (2001). Univariate modeling and forecasting of energy consumption: The case of electricity in Lebanon. Energy, 26(1), 1–14.

Shahbaz, M., Akhtar, N., & Imran, M. (2024). Forecasting Pakistan's energy demand using nonlinear autoregressive models. Energy Forecasting and Economics, 7(2), 58–74.

Suganthi, L., & Samuel, A. A. (2012). Energy models for demand forecasting—A review. Renewable and Sustainable Energy Reviews, 16(2), 1223–1240.

Tariq, B., Rauf, A., & Hussnain, M. (2025). Real-time gas monitoring and distribution optimization in metropolitan areas: A case study of Karachi. Urban Energy Journal, 14(1), 102–118.

Usama, M., Sohail, A., & Perwez, U. (2015). The long-term forecast of Pakistan's electricity supply and demand: An application of long range energy alternatives planning. Energy, 93, 2423–2435.

Waqar, H., Alam, S. H., & Qureshi, A. (2023). Hybrid ARIMA-LSTM models for improving gas demand forecasts in South Asia. International Journal of Energy and AI, 6(3), 91–105.

Yousuf, U., & Qamar, R. (2023). Linking energy modeling with public policy: A framework for low-carbon development in Pakistan. Policy & Energy Review, 9(4), 122–138.

Zuberi, M. J. S., & Ali, S. F. (2015). Greenhouse effect reduction by recovering energy from waste landfills in Pakistan. Renewable and Sustainable Energy Reviews, 44, 117–131.