



Forecasting The Electricity Consumption by Domestic and Industrial Sector in Nepal

Abstract: Forecasting the electricity consumption is crucial for efficient electricity supply management, strategic energy planning as well as policy formulation. This study had aimed to forecast the electricity consumption in Nepal by household and industrial sector by using the ARIMA (Auto Regressive Integrated Moving Average) method. The study incorporates the historical data from 1975 to 2023 A.D. sourced from Nepal Electricity Authority (NEA). and forecast the consumption in both sectors from 2024 to 2033. The study predicts that the sector will continue to experience significant growth in consumption. within the study period the average annual growth rate of consumption in the domestic sector will be 8-9 % while in the industrial sector it will be 10-11%. During the initial years the household sector consumption appears to be higher, but the industrial sector is likely to surpass the domestic sector by 2027.

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Introduction

Worldwide energy consumption is rising rapidly because of the increased human population, continuous pressure for better living standards, emphasis on large-scale industrialization in developing countries, and the need to sustain positive economic growth rates (Bianco et al. 2009). The growth of electricity consumption occurred almost annually during the last 50 years, except in the early 1980s and 2009, following the global financial crisis. It is estimated that global electricity consumption grows around 1 % to 2 % per year (Ritchie et al., 2024). The increasing trend of using the internet has also contributed to the over consumption of electricity in Nepal. In a developing country like Nepal “55 percent of the total population, now use the internet in Nepal” (Tiwari, 2023, as cited in Sherma, 2024, p. 83). The overestimation of consumption leads to superfluous idle capacity, which results in wasted financial resources. In contrast, underestimation would lead to higher operational costs for energy suppliers and would cause potential energy outages. Therefore, modeling electricity consumption with good accuracy becomes vital to avoid costly mistakes

(Kaytez et al., 2015). Nepal has abundant resources. The three major river systems of the country and their smaller tributaries offer 83,000 megawatts of theoretical power and approximately 42,000 MW of power, which is a technically and economically viable hydroelectric potential (Bergner, 2013). The Roadmap for Energy Development has been implemented by declaring the Energy and Water Resources Decade (2018 - 2028) to contribute to fulfill the national aspirations of a prosperous and happy Nepal through the development of energy sector (MOF, 2024). Electricity has been considered the main driving factor for economic growth In Nepal. The sixteenth periodic plan aimed to produce 11,769 MW of electricity, along with per capita power consumption increased to 700 kilowatt/hour. This periodic plan has aimed to earn Rs 40 billion rupees and to contribute 4% of the energy sector to reduce total trade deficit of the Country by the end of this periodic plan (NPC, 2020). In the past, mainly between 2006 and 2016, AD Nepal endured a crippling power supply, and experienced power outages of up to 16 hours a day in the summer. The underperforming electricity sector in Nepal, with the inadequate and unreliable supply of poor-quality electricity, was a major development constraint (G. R. Timilsina et al., 2018). The reliable power supply would have increased the country's annual gross domestic product by almost 7 % and annual investment would have been 48% higher. Nepal has lost a total of 11 billion us dollar value of GDP in that period (G. Timilsina & Stein-buks, 2021). Given these opportunities and challenges, effective forecasting methods are required for planning energy production, distribution, and investment.

Domestic and industrial sectors account for major electricity consumption. In



Fiscal Year (FY) 2023, the total availability of electricity in Nepal was 12,369 MU, which was 6% more than that in the previous year. In that FY the total internal sales were 9347 MU of which 4309 MU (approximately 46.10%) was sold to the domestic sector and 3694 MU (approximately 39.52%) was sold to the industrial sector (NEA, 2024). The consumption forecasting in these sectors is critical for overall estimating the production for future management of the supply and determining the investment required to meet the power demand in the future, and this study predicts the consumption of electricity by the domestic and industrial sectors. This research also identified which sector (Domestic or Industrial) will consume more energy in the future, and to develop consistent and robust electricity consumption forecasting, the autoregressive integrated moving average (ARIMA) Model was Used.

Literature Review

Forecasting energy consumption plays a vital role in short- and long-term energy planning for both policymakers and related organizations in any country. In the related literature, many researchers applied different methods such as moving average, multiple regression, exponential smoothing, neural network, Grey, etc. to forecast energy consumption on sectoral bases or total (Ozturk & Ozturk, 2018). Nichiforov et al. (2017) had presented two approaches for energy consumption forecast, ARIMA model and a non-linear auto-regressive neural network (NAR) model. The study found that performance of the ARIMA model is better than the NAR model by comparing the predictive error values. Hussain et al. (2016) applied the Holt Winter and ARIMA models to forecast electricity consumption in Pakistan and found that electricity consumption would continue to increase throughout the projected period, demand would be the highest in the household sector compared to all other sectors, and the increase in energy generation would be less than the increase in total electricity consumption. Yasmeen and Sharif (2014) reported a similar result, finding that the forecast model and forecast values reveal that electricity consumption increases over time. Sarkodie (2017) used the ARIMA model to forecast Ghana's Electricity Consumption by 2030. Using a time series spanning from 1980 to

2013, evidence from the ARIMA forecast shows that Ghana's electricity consumption will grow from 8.52 billion kWh in 2012 to 9.56 billion kWh in 2030 in the predicted duration.

Anik and Rahman (2021) forecasted that the demand for energy in Bangladesh will continue to grow, and the aggregate demand for energy will increase by 400 % by 2038 under the business-as-usual scenario. The major source of energy in Bangladesh is expected to run out within two decades, and the country will be more exposed to external shocks and volatility in the international energy markets. A similar study was conducted by Rabbi et al. (2020), using an autoregressive integrated moving average with exogenous ARIMAX to forecast the demand for electricity from 2019 to 2021. They concluded that the demand for electricity will increase annually. While going through the literature, it was found that electricity forecasting was basically made for all sectors, no study was found that it had made forecasts on a sector-wise basis, but this study attempted to forecast electricity forecasting based on the domestic and industrial sectors.

Methodology

3.1 Source of Data

This study uses electricity consumption by the Domestic Sector (DC) and industrial sector (IC). The dataset used in this study was retrieved from the Nepal Electricity Authority (NEA). Annual electricity consumption from 1975 to 2023 is gigawatt hours (GWh). This study had made an attempted to forecast electricity consumption by the domestic and industrial sectors up to 2033, which is a Ten -year annual forecast.

3.2 Box-Jenkins (BJ) Methodology

Box and Jenkins of Time Series Analysis: Forecasting and Control ushered in a new generation of forecasting tools. Popularly known as the Box-Jenkins (BJ) methodology but technically known as the ARIMA methodology. (Gujarati & Porter, 2009) .The method consists of four steps

Table 1: Process of Box-Jenkins (BJ) Methodology

1. Identification of the Model (Choose Tentative p,d,q)	
2. Parameter Estimation of The Chosen Model	
3. Diagnostic Checking	
Yes, Go to Step 4	No Go to Step 1
4. Forecasting	

3.3 Unit Root test

Suppose that each of the variables in the model is represented by Y_t

$$Y_t = \phi Y_{t-1} + \varepsilon_t$$

where ε_t is an error term that is a random walk.

When $\phi = 1$, the variable Y_t is not stationary because Y_t is still influenced by Y_{t-1}

When $\phi = 0$, the variable Y_t is stationary because $Y_t = \varepsilon_t$

The Augmented Dicky Fuller Test (ADF) was performed for the Unity root test. To use a time series for prediction, it must be independently and identically distributed (i. i.d.). This means that there was no autocorrelation of the errors. This is based on the following classical assumptions Abonazel & Abd-Elftah (2019)

- $E(\varepsilon_t) = 0$
- $Var(\varepsilon_t) = \sigma^2$
- $Cov(\varepsilon_t, \varepsilon_{t-1}) = 0$

3.4 AR, MA and ARIMA Modeling

The ARIMA model, also known as Box-Jenkins model, has been widely used for short-term forecasting. The autoregressive part (AR) of ARIMA indicates the regression of the time series over its lagged values. Integrated (I) indicates that the values have undergone differentiation, and the moving average (MA) indicates the weighted moving average over regression errors (Nguyen and Hansen, 2017). The ARIMA model is presented by (p, d, q), where the term 'p' indicates the order of partial autocorrelation, the term 'd' reflects the order of difference, and 'q' indicates the order of auto-regression. Jadhav et al. (2017). Auto regressive (AR) model An auto

regressive model of order p, AR (p), can be expressed as

$$X_t = c + \phi_1 X_{t-1} + \phi_2 X_{t-2} + \dots + \phi_p X_{t-p} + \varepsilon_t \quad \text{.....(1)}$$

where ε_t is the error term in the equation

A time series x_t is said to be a moving-average process of order q, MA (q), If

$$X_t = \varepsilon_t - \theta_1 \varepsilon_{t-1} - \theta_2 \varepsilon_{t-2} - \dots - \theta_q \varepsilon_{t-q} \quad \text{.....(2)}$$

.....(2)

A time series x_t is said to follow an auto regressive moving-average process

of order p and q ARMA (p q) process if

$$X_t = c + \alpha_1 X_{t-1} + \dots + \alpha_p X_{t-p} + \varepsilon_t \theta_1 - \dots - \theta_q \varepsilon_{t-1} \quad \text{.....(3)}$$

.....(3)

The general form of ARIMA is (p, d, q). if there exists non-stationary

series, we will take a first-difference of so that becomes stationary, then the

ARIMA (p,1,q) model is

$$\nabla^d X_t = c + \phi_1 \nabla^d X_{t-1} + \dots + \phi_p \nabla^d X_{t-p} + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \dots + \theta_q \varepsilon_{t-q} \quad \text{.....(4)}$$

.....(4)

Where

But if p=q=0 in equation (4), then the model be- comes a random walk model which classified as ARIMA(0,1,0) (Nochai&Nochai,2006).

4.1 Descriptive Analysis

4 Results and Discussion

Table 2: Descriptive Analysis of Variables

Variables		Obs	Mean	Std. Dev.	Min	Max	Skew.	Kurt.
DC		49	875.071	1006.937	54.09	3896.7	1.543	4.492
IC		49	773.856	884.411	21.392	3586.21	1.681	5.265

4.2 Stationarity Test

To examine the stationarity both series have been transforming into the logarithmic form then to test unit root Dicky fuller test is used to check the stationarity.

The null hypothesis for testing unit root test.

H_0 = The series has unit root test

Table 3 : Stationarity test of Variables

At Level			
With Constant		LIC	LDC
	t- statistics	-1.856	0.026
	Prob	0.349	0.973
With Constant & Trend	t - statistics	-3.79	-6.288
	Prob	0.025**	0.00***
At First Difference			
With Constant		D(LIC)	D(LDC)
	t - statistics	-9.855	-14.277
	Prob	0.00***	0.000***
With Constant & Trend	t- statistics	-9.971	-14.15
	Prob	0.000	0.000

a: (*) Significant at the 10%; (**) Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

At level

The Constant t-statistics for LDC and LIC were 0.026 and -1.856, respectively. The p-values of both series are 0.349 and 0.973, respectively, which are greater than the 5% significance level. Therefore, we fail to reject the null hypothesis and conclude that a unit root exists in the series. However, with constant and

trend, the t statistics of LIC and LDC are -3.79 and -6.288, respectively, while the p value of LIC is 0.025 and LDC is 0.00, which are stationary at a 5% level of significance.

At First Differenced

With a constant t stat for LIC of -9.88 and for LDC of -14.277. the P VALUE for both sectors is 0.00. Similarly, the trend and constant t-stat are -9.971for LIC and -14.15 for LDC. The p-values for both series were 0.000. Therefore, we reject the null hypothesis that the series has a unit root test and conclude that the series is stationary at first difference at the 1% level of significance.

4.3 Identification of Model

The appropriate component of autoregressive and moving average order can be found by the analysis of autocorrelation and partial autocorrelation. The value of autocorrelation tells us order of moving average while the value partial autocorrelation suggests the order of autoregression.

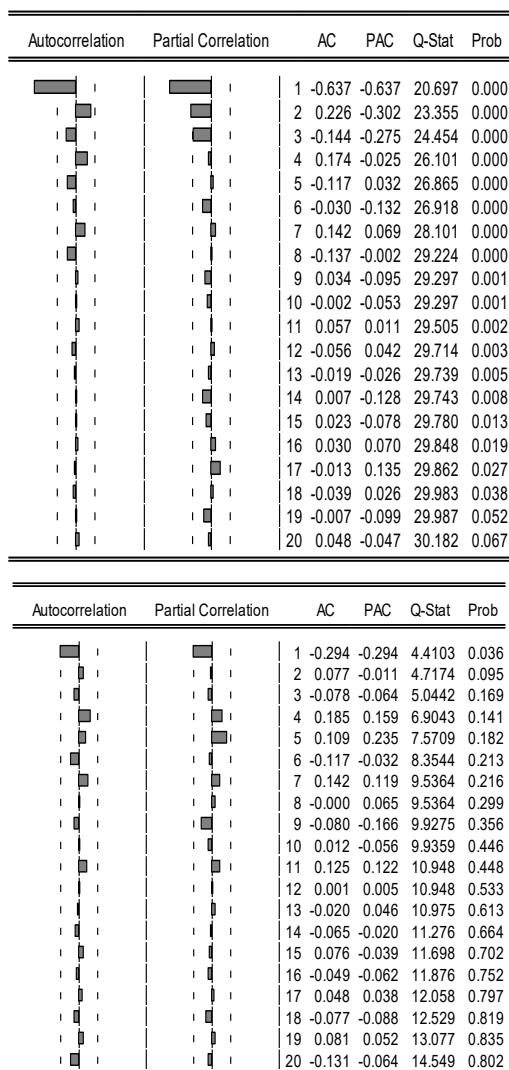


Fig 1: Autocorrelation and partial Autocorrelation of Domestic and Industrial Sector

The above figure shows the autocorrelation function (ACF) and partial autocorrelation function (PACF) of the domestic (upper) and industrial (lower) sectors. The PACF and ACF help to determine the order of autoregressive (P) and moving average (q). The correlation that fell outside the shaded area (95 percent confidence band) was considered significant. The order of p for domestic consumption (upper figure) is 1, 2, 3 and order of q is 1. Similarly, the order of p in the industrial sector (lower fig) is one, whereas the order of q is one. Because both variables are stationary at first difference, the order of d is one. The possible model for the domestic sector is (1,1,1) (2,1,1) (3,1,1) and the industrial sector is (1,1,1).

4.4 Selection of Best Model

From the above figure1 Arima (1,1,1) has been selected as the best model for the industrial sector, but for the domestic sector, models (1,1,1) (2,1,1) and (3,1,1) have been proposed, and these models are subject to testing. To select the best model, three criteria were selected: Akaike information criterion (AIC), Schwarz Information Criterion (SIC), Hannan Quinn criterion (HQC), and Sum of Square Residual (SSR). For the model that has the lowest value of these selection criteria, the best model is. From Table 4, models (1,1,1) have the lowest value of AIC, SIC, HQC, and SSR among the other models, so it is considered as the most appropriate model.

Table 4 : Selection of Best Model

Domestic Sector				
Model	AIC	SIC	HQC	SSR
(1,1,1)	-3.540	-3.384	-3.481	0.0677
(2,1,1)	-3.521	-3.365	-3.462	0.0720
(3,1,1)	-3.478	-3.322	-3.219	0.0688

4.5 Stability Test

From table 4 the best model for domestic consumption has been identified as the (1,1,1) and for industrial consumption also (1,1,1). The stability of the proposed model was determined by plotting the inverse root of the AR/MA. The plot shows that AR roots and MA roots are inside the unit circle, and we conclude that the estimated ARMA process is



stationary. The proposed model for both sectors can be subject to forecasting.

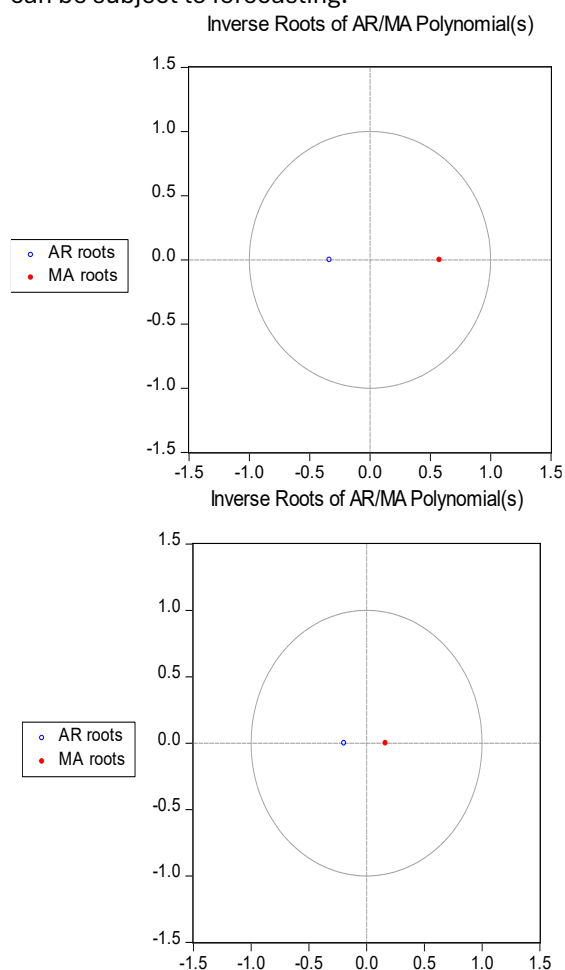


Fig 2(a) : Stability of Domestic Sector consumption

Fig2(b): Stability of Industrial Sector consumption

4.6 Forecasting consumption in both Sector.

The graph below shows the trends of historical energy consumption and the forecasted value of the domestic and industrial sectors. In the graph, UB and LB are the upper (blue) and lower (red) bounds, respectively. The black line is the value of previous consumption, while the Green Line in the Shaded area is the forecasted value of the Boths sector. From the figure, it was concluded that consumption will continuously increase during the study duration (2024-2025).

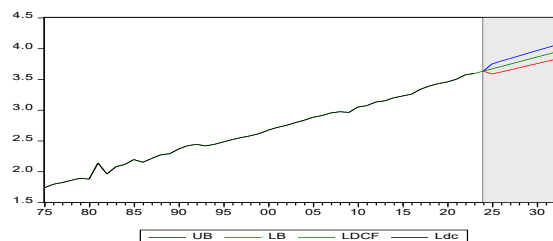


Fig 3 (a) : Trend of Forecasted consumption in Domestic Sector

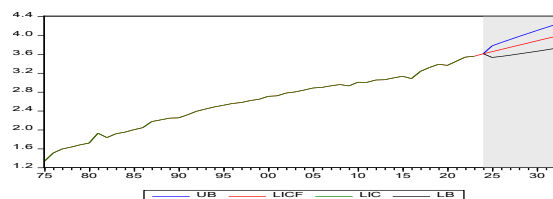


Fig 3(b) : Trend of Forecasted consumption in Industrial Sector

4.7 Comparison of Forecasted Value

Table (4) shows the forecasted values for the domestic sector and industry from 2024 to 2033. The approximate growth within the forecasted period (2024–2033) is expected to be 2.2 times for the domestic sector, with an annual growth rate of 8 to 9%. prediction shows that the annual growth rate of the industrial sector will be 10-11% while that of the domestic sector is likely to increase significantly up to the study period. Although consumption in the domestic sector is higher in the first three years (up to 2026), the industrial sector will outperform domestic consumption from 2027.

Table 5: Forecasted Value of Each Sector
Source: Authors' own calculation

FY	DC_F	IC_F
2024	4225.974182	4050.288615
2025	4628.805288	4484.244061
2026	5053.242779	4983.921254
2027	5522.717544	5535.122282
2028	6033.574035	6148.179408
2029	6592.501021	6828.944177
2030	7202.907002	7585.129108
2031	7869.939786	8425.039184
2032	8598.70415	9357.955405
2033	9394.967319	10394.17431

Conclusion and Discussion

From the study, it was concluded that the consumption of electricity in both sectors (Domestic and Industrial) will increase significantly. The consumption will be more than double in 2033 in both sectors compared to 2024, with annual growth rate of 8 - 9% in domestic sector and 10-11 % in industrial sector. Although the volume of consumption in the domestic sector is higher in the initial years, the industrial sector will surpass consumption after 2027.

There is a departure from neoclassical economics, which included only capital, labour, and technology as factors of production, to one that now includes energy as a factor of production (Alam, 2006). Georgescu-Roegen (1971) argues that energy is a primary factor in production. This means that energy is a fundamental factor in production, spurring higher productivity and economic activity. However, the energy used in the domestic sector is limited use, as it is basically used for an individual's well-being and quality of life; it does not contribute much to production and job creation.

Energy is used in the industrial sector for a wide range of purposes, such as production and assembling, steam and co-generation, processing heating and cooling, lighting, and air conditioning for buildings (EIA, 2021).

Energy consumption in the industrial sector has a multifaceted impact and can become the cornerstone of economic growth. By 2027, the Nepalese industrial sector will outpace the consumption of the domestic sector, which will increase the per labor output ratio, reduce production costs, foster high-value production, and align production with renewable energy, which also ensures sustainable development. In summary, more economic progress is likely to occur in the days to come.

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