Macroeconomics and Monetary Economics

Univariate Modelling and Forecasting of Energy Consumption: The Case Study of Electricity in Pakistan

Rizwan Fazal[1], Ameer Khalil ur Rehman[2], Asad Shahbaz[3]

Abstract: Demand and supply side assessment are the two foremost important components of energy management and planning. Unfortunately, for the past twenty years Pakistan is confronting extremely serious issues with energy management such as electricity followed by institutional incompetence and lack of policy response. This is due to the fact that the country neither has long term energy plans nor short-term solutions to deal with energy crisis. This study outlines overall consumption of electricity and forecasting its various components. The interminable crisis of electricity affects all sectors of economy. The study deals with this particular aspect and applies Holt-winter and ARIMA models for the forecasting. The outcomes of both the models suggest that ARIMA model is more reliable for forecasting as compared to Holt-winter model. Estimated results affirm the tendency of increasing demand in all the indices which show an alarming position in future. Household sector will have the highest energy demand in 2030, followed by industrial sector. Thus, due to the ever increasing demand of electricity energy, government should initiate different renewable sources of power production such as hydal and solar energy to overcome the shortfall of electricity energy as well as sustainability in economy.

Keywords: Electricity; Energy; Holt-winter; ARIMA; Forecasting; Pakistan;

JEL Classification: Energy

1. Introduction

Energy is the basic necessity for the human as well as socioeconomic development of an economy. In more detail to express the growth of economy the contribution of energy per capita is required. Pakistan energy needs is highly dependent on oil, natural gas and gasoline. These sources of energy contribute more than 80 percent of the total electricity generation in the country. Electricity is the main driver of economic activities and the utmost requirement for the development of industrial,

[1] PhD Scholar, Pakistan Institute of Development Economics, Pakistan, Address: Quaid-i-Azam University Campus‹ Islamabad, Islamabad Capital Territory 44000, Pakistan, Corresponding author: rizwanfazal_15@pide.edu.pk.
[2] CEO, Da Bank of Afghanistan, Afghanistan, E-mail: Rizwanfazal_15@pide.edu.pk.
[3] PhD Scholar, Pakistan Institute of Development Economics, Islamabad, Address: Quaid-i-Azam University Campus Islamabad, Islamabad Capital Territory 44000, Pakistan, E-mail: rizwanfazal_15@pide.edu.pk.

agricultural, and services sector. It is one of the most important source of energy in Pakistan but unfortunately, Pakistan has been facing severe energy crisis from its inception which retarded economic growth and development. The current spate of energy crisis has become a daunting task and haunting GDP growth of Pakistan. With 2.41% population growth, country would need at least 6% GDP growth to overcome unemployment rate and poverty level (PIP, 2015). In such abysmal situation government does not pay any heed to energy generation. As the result all sectors has badly suffered from energy crisis and their contribution in GDP sharply declined. The growing trend of population will further increase demand for energy. The population of Pakistan was about 80 million and electricity consumption was 24759 thousand metric tons and production was 20922 thousand metric tons of oil equivalent in the time period 1980. The population grew to 176.17 Million and electricity consumption was 84844 thousand metric tons and production was 65066 thousand metric tons of oil equivalent in the period 2011 (SESRIC, 2014). But the current demand and supply gap has further widen than it was ever before. Electricity shortfall had reached 4250MW while demand is 16400MW and generation is 12150MW (PEPCO, 2013). Households and Industrial sector mainly consumed electricity energy that is 45.6% and 28.4% respectively (PES, 2012).

The figures issued by Hydrocarbon development institute of Pakistan (HDIP, 2015-16) revealed that the primary commercial energy supplies reached 70 million TOE in 2015. The total shares of oil, gas, LPG, LNG, coal and imported electricity was documented 35.5%, 42.7%, 0.7%, 0.7%, 7.0% 0.2% respectively in 2014-15.

Energy across various sectors from 1992 to 2015

Fuel type	Years	Domestic	Commercial	Industrial	Agri.	Transp.	Other Govt.
	1992	33.8%	6.3%	36.2%	17%	0.09%	6.23%
Elec	2000	47.6%	5.5%	28.9%	9.9%	0.03%	8.40%
	2015	48.3%	7.5%	29.1%	9.3%	0.00%	5.64%

Furthermore, in 1947 Pakistan had generating capacity of 10.7MW through Hydel power plants, but this figure was elevated to 115MW due to the establishment of Atomic energy research council in 1956. Similarly, in 1958 a separate department WAPDA was established which enhanced electricity production to 119MW, while 781 MW was added to the system in 1965with the construction of Mangla and Tarbela dam in 1970 electricity power generation capacity jumped to 3000MW. From 1992-97 thermal ways of power generation were used which, though elevated power supply to more than 12000MW but on the other hand the cost associated to thermal power generation also increased. Interestingly, in 2005, 450MW surplus was recorded but since then, there was increase in demand of power, however the supply added to the system was not enough to meet the rising demand. Therefore, the country was engulfed by severe power shortage and the power supply was diminished by 6,000 MW. The electricity shortfall in the period 2008-09 was recorded 3338 MW and it was expected to reached 13651 MW by 2020 (PIPB, 2008). Load shedding blackouts became more severe with every passing day. Around 40% to 45% factories have been closed and 7.5% to 8% of labor force lost their jobs due to this dilemma (PES, 2006-07). All the figures confirm that the gap between production and consumption has been enlarging and need proper attention. The study aims to forecast power consumption of Pakistan.

II. Literature Review for Choice of Forecasting Model

Literature relating to forecasting models is complex as many researchers agreed while others disagreed to use forecasting model for policy analysis (Sims, 1986) (Zaman, 2012). (Brandt & Bessler, 1983) confirmed that forecasting methods provide information for policy analysis. Researchers applied variety of methods to predict power consumption. Modelling of energy resource systems for planning and policy development has been rarely conducted in Pakistan. There is very limited work in this area which includes (Hussain, Rahman, & Memon, 2016), (Perwez, Sohail, Perwez, & Sohail, 2014), (IRG, 2010), (PIP, 2015), (NTDC, 2014) discusses different shares of energy systems as a whole. (Hussain, Rahman, & Memon, 2016) estimated demand of service sector by applying three different methods: a) econometric models b) relating energy service demand in particular sector to GDP and c) relating energy service demand to value added of the particular sector. Service energy demand in transport and residential sector was determined through econometric approach using dependent variables while service energy demand in industrial, commercial and agriculture sector was estimated through economic value added and GDP approach. The Service demand projection for agriculture, commercial and industrial sector was based on the service demand of sector in base year multiplied by the ratio of the current year value added and base year value added.

(Saab, Badr & Nasra, 2001) presented forecasting electricity energy consumption in Lebanon for the time period 1990-1999 by applying autoregressive model. (Asad, 2012) forecasted Australian daily electricity energy consumption by using ARIMA model. The study confirms that ARIMA model is the best model for forecasting. (Xie, 1998) presented reliability of ARIMA model for forecasting analysis, while the comparison is made with other forecasting models like Duane model. The study suggests that ARIMA model gives reliable results as compare to other models. (James, 2003; 2008) applied Holt-winter model to forecast demand for electricity. The study confirms that Holt-winter model gives reliable results with minimum mean absolute percentage error (MAPE) and root mean square error (RMSE). (Nasir, Tariq, & Arif, 2007) conducted study on residential demand for electricity in Pakistan using ARDL model major finding of this study was that there is increasing demand for electricity energy as household size increase. Mounir 2009 examined the relationship between per capita energy consumption and per capita Gross Domestic Product using VAR methodology. Major findings of the study were that there is a long run relationship between per capita electricity consumption and per capita GDP. (Erdogdu, 2007) (Azadeh, Ghaderi, & Sohrabkhani, 2007) suggested ANN model while (Lepojević & Anđelković-Pešić, 2011) suggested Holt-Winter model as appropriate for forecasting analysis. (Khan, 2011) Applied ARIMA and Holt-Winter model for forecasting total import in Bangladesh. Taylor 2008 investigated electricity demand for the United Kingdom and found that Holt-Winter methodology gave good forecasting results.

References	Sector	Country	Methodology	Forecasting Period
Saab (2001)	Electricity	Lebanon	ARIMA	Monthly
Ediger (2007)	Primary energy demand	Turkey	ARIMA	2005-2020
Erdogdu (2007)	Electricity	Turkey	ARIMA	2005-2014
Pan (2012)	Energy demand	Taiwan	SARIMA model	2010-2020
Voronin (2014)	Electricity price and demand	Finland	ARIMA	Dayily
Yuan (2016)	Energy consumption	China	Comparing of ARIMA model and GM(1,1) model	2014-2020
Huang (2011)	Energy demand and Supply	Taiwan	LEAP	2008-2030

In addition, (Jon A. Brandt, David A. Bessler, 1983) confirmed that forecasting provided reliable information for policy analysis. Hence, Pakistan needs a more comprehensive, integrated and appropriate policy in the energy sector. Due to the absence of any sound policy, Pakistan has been facing acute crisis of energy which impeded economic growth of Pakistan. State bank of Pakistan had adopted a policy in 1998 for the purpose to enhance growth rate but unfortunately, the policy adversely affected economic growth (Janjua, 2007) . The present study will provide a policy to overcome the current shortfall of electricity in Pakistan. Numerous studies have been conducted to measure the relationship of consumption of different electricity energy commodities as well as test the hypothesis of energy economics. (Anjum Aqeel and Mohammad Sabihuddin Butt, 2001), (Renana, 2002), (Muhammad Nasir and Faiz Ur Rehman, 2011) (Muhammad Shahbaz, Hooi Hooi Lean, 2012), (Mudassir Zaman, Farzana Shaheen ,Azad Haider and Sadia Qamar, 2015). Some researchers have also described that GHG emissions as a function of energy consumption and economic growth in Pakistan

III. Research Methodologies

Data Sources

Secondary data on indices like total electricity energy consumption, household energy consumption, commercial energy consumption, Agricultural energy consumption, industrial energy consumption and street light energy consumption from the time period 1990-2014 is used. Data for the study is taken from State bank of Pakistan and Economic survey of Pakistan.

The ARIMA and Holt-Winter estimating models are mostly applied in literature (Ediger, & Sertac, 2007); (Ujjwal Kumar, VK Jain, 2010). Furthermore, are the appropriate techniques for long haul anticipating utilizing time arrangement information. Thus, these two strategies are connected in the present study and the outcomes are then analyzed. The reasonable model out of these two is distinguished. The ARIMA model has been fruitful for estimating power utilization. (James, 2003; 2008) used this model to estimate power request and reasoned that Holt-Winter gives better conjectures. Since the goal of this paper is to gauge long haul power utilization in Pakistan, ARIMA and Holt-Winter is by all accounts the better decisions and are utilized as a part of the present study.

Autoregressive Integrated Moving Average Methodology (ARIMA)

Steps involved in ARIMA

Box and Jenkins provides the stepwise procedure for the ARIMA analysis. We have the time series data so first stationary or the non-stationary of the series is checked applying DF test and visually through correlogram of the series. If the spikes are outside the 95% band it means, there exist autocorrelation and the series is non-stationary. As a result, we take log difference of the series to make variance and mean constant. If mean and variances of the series are independent of time while covariance between the periods depends only on the distance between the periods, the process is said to be stationary. Ducky Fuller test (DF) is applied to check whether the data is stationary or non-stationary. In this study we have used the Augmented Ducky Fuller Test (ADF) for checking unit root problem.

$$\Delta Y_t = \alpha_t + \beta_t + \rho Y_{t-1} + \varepsilon_t$$

$$H_0 : \rho = 0$$

$$H_1 : \rho \leq 0$$

Ho: series is non stationary; H1: Series is stationary

In ADF test, the lags of the first difference are included in the regression in order to make the error term ε_t white noise and, therefore, the regression is presented in the following form:

$$\Delta Y_t = \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t \text{ Tastați ecuația aici.}$$

To be more specific, we may also include an intercept and a time trend t, after which our model becomes:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha_i \sum_{i=1}^{m} \Delta Y_{t-1} + \varepsilon_t$$

The DF and ADF tests are similar since they have the same asymptotic distribution. In literature, although there exist numerous unit root tests, the most notable and commonly used one is ADF test and, therefore, it has been used in this study (Erdogdu, 2007).

Next step involves determination of p and q orders for AR and MA which is carried out with the help of ACF and PACF which gave idea about the suitable orders of MA and AR respectively. The resulting correlogram, are simply the plots of ACF and PACF against the lag length. The ACF at lag k, denoted by ρ_k, is defined as (Erdogdu, 2010):

$$\rho_k = \frac{\gamma_k}{\gamma_0}$$

where γ_k is the covariance at lag k, γ_0 is the variance. The PACF at lag k, denoted by

$$r_k = r_k - \sum_{k-1}^{k-1} r_j \, r_{k-j} / 1 \sum_{k-1j}^{k-1} r r_j$$

Tow packages Minitab and Eviews are used to analyze the data.

Testing for autocorrelation, heteroscedasticity and significant of coefficient of AR and MA as well as finalizing the model for forecasting using AIC and SBC criterion will be applied. Before we finally selected a forecasting model, we looked for residuals from the estimation in previous step and checked whether any of the autocorrelations and partial correlations of the residuals is individually statistically significant or not. They being statistically significant, meant that the residuals were purely random and there was no need to look for another ARIMA model. In the final step, forecasting was carried out based on the constructed and checked ARIMA model (Erdogdu, 2007). For forecasting evaluation different methods are applicable but RMSE and MAPE are commonly used in literature and provide reliable results so in the present study the same techniques will be applied to measure the model performance. The RMSE and MAPE can be calculated by using the formula given below.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}|(F_i - A_i)^2|}{n}}$$

$$MAPE = \left(\frac{\sum_{i=1}^{n}|(F_i - A_i/A_i|}{n}\right) X\ 100\%$$

where Ai is the actual value and Fi is the forecast value.

Table 1. Description of ARIMA parameters applied in each forecasted time series

Sectors	Fuel type	Parameters ARIMA (p, d, q)	Sectors	Fuel type	Parameters ARIMA(p, d,q)
Domestic	Electricity	ARIMA (1,1,4)	Agriculture	Electricity	ARIMA (2,1,3)
Industrial	Electricity	ARIMA (1,1,4)	Transportation	Electricity	ARIMA (1,1,3)
Commercial	Electricity	ARIMA (1,1,5)	Other Govt.	Electricity	ARIMA (1,1,3)

Source: Authors Calculations derived through Statistical package Eviews

Holt-winter Model Methodology

The holt-winter model forecasting is based on different combination of scales to the exponential and trend component. To construction Holt Winter Forecasting technique, trend and exponentially smoothed components are created to predict total electricity energy consumption by using the formula given below.

$$\boldsymbol{E_t = \alpha(Y_t - S_{t-p}) + (1-\alpha)(E_{ec(t-1)} + T_{ec(t-1)})}$$

$$\boldsymbol{T_t = \beta(E_{ec(t-1)} - E_{ec(t-1)}) + (1-\beta)T_{ec(t-1)}}$$

To Forecast “k” time period the formula is

$$\boldsymbol{F_{ec(t+k)} = E_{ec(t)} + kT_{ec(t)}}$$

Where, E and T shows exponentially smoothed component and trend component respectively. α and b are scalar, which can take value between zero and one. It controls trend as well as smoothness. “Eci” shows determinants of electricity energy consumption like household energy, commercial energy, streetlight energy, agricultural energy and industrial energy.

Where, Yt= Actual values, Ft= predicted values, n= observations, Yt-Ft= ei, Statistical package, Eviews and Minitab are used for estimation.

IV. Results and Discussion

ARIMA and Holt-Winter forecasting models is applied with the objective to identify reliable forecast model. Estimated results in table 1 demonstrate that the ARIMA is reliable for forecasting electricity consumption as it has minimum RMSE and MAPE values for total electricity consumption and its components as compare to Holt-Winter model.

Table 2. Error measures of the ARIMA and Holt-Winter Forecasting Models

Models Variable	Holt-Winter		ARIMA	
	RMSE	**MAPE**	**RMSE**	**MAPE**
Total electricity consumption	2431.1	93.4	1318.8	6.3
Household consumption	1265.9	74.2	984.2	9.8
Industrial consumption	1013.3	529.8	724.8	5.2
Agricultural consumption	1497.5	652.1	901.3	19.6
Commercial Consumption	4205.8	201.6	507.9	5.7
Street light consumption	55.2	286.9	39.1	16.9

Source: Authors Calculations derived through Statistical package Minitab

Note: RMSE Stand for Root Mean Square Error

MAPE stand for mean absolute square Error

Estimated forecasted results of ARIMA are in three different parts which are upper limits, lower limits, and forecasted values. Upper and lower limits give us a confidence interval of 95%, if the forecasted value lie inside the confident interval then parameters are stable and forecasted value is consistent and future policy on the basis of these results are reliable. In this study we have found that forecasted value lies inside the confident interval of 95%.

Table 3. Forecasting electricity energy consumption (GWH) up to 2030

Projected	Household	Commercial	Industrial	Agricultural	Street Light
2015	39931.3	6671.1	27012.3	10121.5	541.985
2016	42141.1	6900.2	28523.8	10436.3	556.124
2017	43351.4	7210.1	29910.0	10991.9	577.335
2018	45562.1	7299.8	31002.9	11351.8	596.146
2019	47752.5	8259.4	32512.4	11698.2	614.964
2020	50952.9	8521.3	33986	11992.2	633.634
2021	52941.1	8763.9	35113.3	12311.9	651.722
2022	54325.5	8996.7	36932.2	12785.2	670.434
2023	55902.7	9115.9	37873.5	13845.8	689.632
2024	58513.5	9670.75	39379	13828.1	707.956
2025	60596.4	10010.7	40746.7	14248.5	726.622
2026	62680.1	10350.7	42114.3	14668.9	745.289
2027	64763.4	10690.6	43482	15089.3	763.956
2028	64763.4	11030.6	44849.7	15509.7	782.622
2029	68930.7	11370.6	46217.3	15930.1	801.289
2030	71013.9	11710.5	47585	16350.5	819.956

Source: Authors Calculations derived through Statistical package Minitab

Table 2 explains forecasts of total electricity consumption and its component estimated. It is found from the results that there is a continuous increasing tendency in all components of total electricity consumption. The results further suggest that household will be the most highly energy consumed sector (71013.9 GWH) in 2030. The highest energy demand will come from household sector, followed by Industrial sector (47585 GWH), agricultural sector (16350.5 GWH) and Commercial energy sector (11710.5 GWH). The results show an alarming position or an extensive shortage of electricity in future.

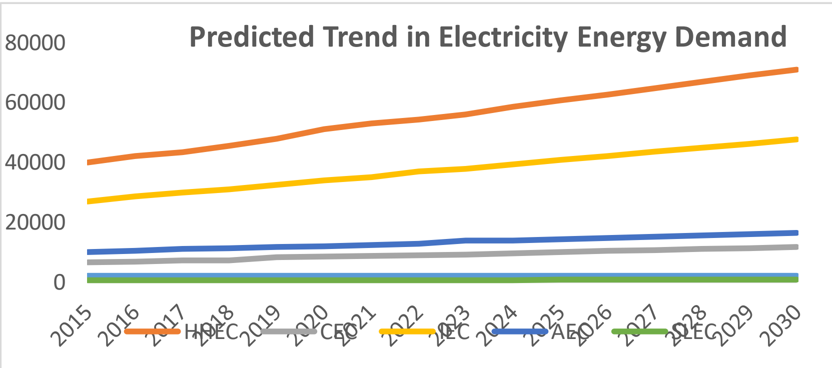

Figure 1. Future Electricity Demand Trend

Note: HHEC stand for Household Electricity Consumption

CEC stand for Commercial Electricity Consumption

IEC stand for Lahore Electricity Consumption

AEC stand for Agricultural Electricity Consumption

SLEC stand for Street Light Electricity Consumption

The electricity utilization trend in Pakistan is rising consistently in different sectors but household sector has the highest forecast value as compare to other components of total electricity consumption. The expanding pattern of electricity utilization has numerous reasons in Pakistan. Industrial sector is one of the most important sector for the economic growth of a country, unfortunately industrial sector is affected due to less supply of electricity which directly affect export of economy and hence export decline. The economy is developing at the rate of 3%, while FDI enhanced from 469 million dollars in the year 2000 to 2205 million dollars in the year 2010 (PES, 2012). According to Private Power and Infrastructure Board report about 65 to 75% of the population has the availability of electricity in Pakistan. Total numbers of towns availing electricity energy are increased from 609 to 125495 in the year 1958 and 2008 respectively (PWDP, 2015). This is a clear picture of electricity energy demand in Pakistan. The abovementioned study suggests that because of increase in economic activities in different sectors as well as increase in population, electricity demand will also increase in future. Moreover, with increase in energy demand the supply side also got improvement but still the demand exceed supply (NBP, 2008). Abbas 2011 provide official statistics of Pakistan and account 22% increase in demand of electricity by 2015 and a shortfall of about 64% by the year 2030. Moreover, Inadvertent policies, political instability and high corruption in mega projects related to the energy sector are another obstacle in tackling the energy crises in Pakistan. Nandipur Power Project is a 425 Mega Watt thermal power project. Unfortunately, after the opening ceremony, the plant remained operational for four to six days and then stopped, due to less management and inadvertent policy.

Renewable and non-renewable energy demand is an essential factor of economic development. The research on energy and growth nexus is split in different competing hypotheses. The energy demand depends on different factors like real income, relative prices, the available technology and lifestyle. Economic growth and development is closely connected to growth in energy demand because more energy required result the higher the economic growth. Hydropower project is the main source of renewable energy. About 1200 MW electricity are added to total energy due to installation of small hydropower projects, which provide cheap electricity to rural population. Currently Pakistan generate electricity mainly through fossile fuel as compare to hydro and nuclear as shown the figure.

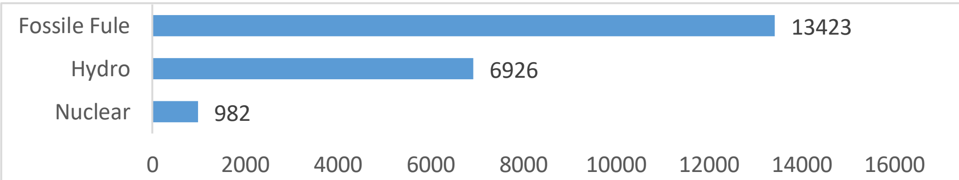

Figure 2. Capacity of Different Electricity Sources

Pakistan is also facing the problems of electricity theft. In many big cities like Karachi and Lahore, the electricity theft is on a peak. According to planning commission report, about 850 billion rupees' loss had been recorded in the year 2012 (PC, 2013).

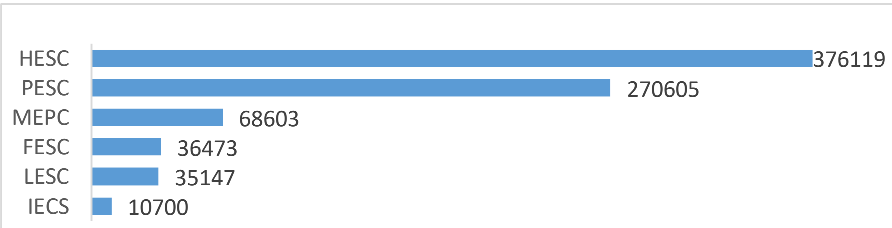

Figure 3. Number of Electricity Theft Cases 2013

Note: HHEC stand for Household Electricity Consumption

CEC stand for Commercial Electricity Consumption

IEC stand for Lahore Electricity Consumption

AEC stand for Agricultural Electricity Consumption

SLEC stand for Street Light Electricity Consumption

Besides this, most of the regions of a country like FATA there is no concept of a billing system. Also, some government organizations do not pay their electricity bills which results in the electricity crisis in Pakistan. In view of current ground realities and estimated results, it is impossible to handle such energy crises by introducing short term project. Introducing short term projects will reduce energy crises on a temporary basis but these are like economic bubbles which break down quickly. The past Government produced energy through oil and never giving attention in solving the issues of energy by operating long term project and this is the basic reason that current Government is facing the huge sum of the energy crisis. India, Bosnia, and Bulgaria produce electricity from coal 68%, 70% and 55% respectively while in 2013 Pakistan was the 28^{th} biggest coal reserve in the world (Wikipedia, 2013) but unfortunately the country only produce about 0.1% of total electricity from coal (WDI). To tackle the problem on emergency basis the government should focus on coal, solar energy as well as wind energy to minimize the electricity demand in the country. Pakistan is likely to produce 50,000 MW to 100,000 MW with the help of solar electricity while the country has also the potential to generate 10000 MW to 50000 MW from wind energy sector. The most likely areas for wind electricity are Jhampir, Keti-Bandar and Bin-Qasim Karachi. The government should focus to install such technologies which will add electricity energy to system and decrease demand of electricity.

V. Conclusion and Recommendations

Energy data record keeping is still in its juvenile stages in Pakistan and therefore sub-sectoral detailed energy statistics are missing. We conducted this study to provide an updated energy outlook for the country that will be useful in energy planning and achieving energy development. The result from analysis conforms that there is in increasing trend in total electricity consumption and its components. The comparison is made between Holt-winter and ARIMA forecasting model. From the estimated statistics it is found that ARIMA model is reliable for forecasting. Forecasted results suggest that there is a continuous increase in electricity consumption in all sectors of the economy. The gap between demand and supply increases by every passing day. So policymakers should focus on the issue appropriately. Moreover, the government should start the long run as well as short run projects like coals, solar electricity production, hydropower, and wind energy to produce electricity. Therefore, it is recommended that, the government should strengthen institutes involved in energy supply and revise policies based on solid research to promote energy security, sustainability and adopt such multi-dimensional policies to overcome all such problems.

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