Volume – 6, Issue – 6, October – 2020

Long Term Electricity Demand Forecasting for Saudi Arabia

Fares Ramzi* & Mustafa Alidrisi

Department of Industrial Engineering, King Abdulaziz University, Jeddah, Saudi Arabia
*Corresponding Author E-mail: fares.91.ramzi@gmail.com

Abstract: This research is about electricity demand forecasting in Saudi Arabia till the year 2025. The data on demand were collected from King Abdullah Petroleum Studies and Research Center, for the four regions in Saudi Arabia namely, western, central, eastern, and southern regions. The data pattern for the regions were studied and all showed monthly seasonality with slight variations. After that three forecasting methods were applied starting with the time series decomposition method with a multiplicative model, The Box-Jenkins methodology (ARIMA) and Winter's triple smoothing method to find the forecast of electricity demand for each region. Then, those forecasts were combined to obtain the total demand of electricity for Saudi Arabia. The forecast for the 96 months from Jan. 2018 until Dec. 2025 were obtained which showed that the demand will continue to grow for all regions with a peak at the summer season. An analysis of electricity demand factors was also studied using fishbone and regression analysis to identify the most important factors affecting electricity demand in Saudi Arabia, which were found to be: populations, number of subscribers, number of factories, CO2 emissions, and air temperature. Comparison of the forecasting errors measurements indicates that, in general , the time series decomposition method is the best model, however, a combined model was also generated to optimize accuracy, which shows that peak demand in August 2025 will be 63.30115 GW.

Keywords: Electricity Demand Forecasting, Energy, Seasonal, Time Series, Saudi Arabia, Electricity Demand Factors, Analysis.

1. INTRODUCTION

Energy consumption continues to grow over the years. This is due to population and economic growth [1]. In countries that have a very hot climate such as Saudi Arabia, energy consumption is increasing specially in summer seasons due to air conditioning (AC) and other cooling equipment usages which constitute 70% of total building electricity usage in Saudi Arabia [2]. In the last 50 years, the population of Saudi Arabia rised to more than 27 million [3]. Due to the population and economic growth, the energy sector which also includes the electricity sector in Saudi Arabia becomes very important. During 1990 to 2010, electricity consumption in Saudi Arabia increased to a peak load of 24 GW in 2001 which is 25 times higher than the peak load of year 1975. In 2023, the expectations for electricity demand will approach a peak load of 60 GW [4]. The peak demand for electricity usually happens during summer season as the consumption is coming from the usage of AC [2]. Based on Ministry of Energy in Saudi Arabia, the electricity consumption was 286 million MWh in 2015 with a 4.2% growth rate compared to 2014. Furthermore, the average electricity consumption growth rate is between 6% to 7 % annually [2], [5].

1.2 Statement of the Problem

Population, Economical, environmental conditions, and Industrial growth are the main factors affecting energy and electricity demand [1], [6] Even though energy is a good resource which everyone enjoys its advantages, it has also disadvantage. Air pollution and Climate change the main problems of fossil energy [7], in addition to the lack of safety on Nuclear energy [8]. Therefore, renewable energy is coming to be the future solution of energy problems [9]. Thus, energy policy and planning researchers need to integrate between those resources in order to achieve the optimal mix of these resources to cover the demand firstly, with minimizing energy problems from pollution and maximizing safety, at the minimum cost. Since population and demand continue to grow every year in Saudi Arabia, energy demand and its problems are continuing to grow in parallel with this increase. Forecasting is defined as estimating the future by knowing the past. It is an essential key tool needed for planning. Electricity demand forecasting is required since electricity demand is playing a big role in setting energy policies for countries [10].

In Addition, electricity demand forecasting allows planners to see the expected future demand to have appropriate plans that meet the demand without facing any shortages. For this reason, this research study aims at forecasting electricity demand in Saudi Arabia by the year 2025.

1.3 The Objective of The Research

The objective of this research is to develop a forecast of the electricity demand in Saudi Arabia till the year 2025. Some of the specific objectives of this study are:

1. Obtain reliable forecasts of the electricity demand in each region of Saudi Arabia, mainly Western, Central, Eastern, and Southern regions.
2. Develop forecasts using various forecasting techniques and methods and compare their accuracy using standard error estimates.
3. Identify the main factors causing the increase in electricity demand in Saudi Arabia.

2. LITERATURE REVIEW

Singh, in [11] have summarized the different techniques of electricity load forecasting, he categorized the forecasting techniques into three major techniques which are Traditional Forecasting Techniques, Modified Traditional Techniques, and Soft Computing Techniques where the Traditional Forecasting Techniques includes Regression Methods, Multiple Regression Methods, Exponential Smoothing, and Iterative Reweighed Least Squares. Modified Traditional Techniques includes Adaptive Demand Forecasting, Stochastic Time Series, Autoregressive Model (AR), Autoregressive Moving Average ARMA, Autoregressive Integrated Moving Average ARIMA, and Support Victor Machine Based Technique. And finally, Soft Computing Techniques are Genetic Algorithm, Fuzzy Logic, Neural Networks, and Knowledge-Based Expert System. Among those many different techniques A. Singh, concluded that Soft Computing Techniques are much better than the other techniques, however, in the future trending techniques will be hybrid by mixing those techniques. F. Yasmeen in [1], categorized electricity consumption forecast into short-term forecasting used for daily forecasting and long-term forecast applied in strategic planning. In their case, they applied Functional Time Series FTS technique which have also previously applied in different applications such as demographic and breast cancer death rate prediction, the data which they used were for 21 year from 1990 until 2011 in order to have 10 years forecast. Mean Absolute Percentage Error MAPE were used to measure forecasting accuracy. Y. Lee, in [12] used six time series tools to forecast electricity consumption in University Tun Hussein Onn Malaysia namely; Simple Moving Average SMA, Weighted Moving Average WMA, Simple Exponential Smoothing SES, Holt Linear Trend HLT, Holt-Winters HW, and Centered Moving

Average CMA. Four error measurements tools where used in his study which were, Mean Absolute Error MAE, Mean Absolute Percentage Error MAPE, Mean Square Error MSE, and Root Mean Square Error RMSE. The conclusion showed that HW had the least MAE and MAPE, however CMA had the lowest MSE and RMSE. According to Lewis as mentioned in Y. Lee's paper [12], the best forecasting accuracy measurement is MAPE, and based on that they decided to choose HW method to follow. S. Ozturk, in [13] used ARIMA model with 45 years data starting from 1970 to 2015 and have forecasted energy consumption in Turkey for the next 25 years period using ARIMA models for each energy source of Coal, Oil, Gas and renewable and found that ARIMA (1,1,1) represents Coal model, ARIMA (0,1,0) represent Oil model, ARIMA (0,0,0) and ARIMA (1,1,0) represents Gas and Renewable consecutively, however they have developed ARIMA (0,1,2) for total energy consumption model. Modeling done using E-Views 9 software. Z. Mohamed, in [14] applied six models to forecast electricity consumption in New Zealand. The models were Logistic Model, Combined Model, ARIMA Models, Harvey Logistic, Harvey Model, and Variable Asymptote Logistic VAL. MAPE were used to measure forecasting accuracy. After comparison among the models, Harvey model had the advantage for domestic and total consumption forecasting, however, Harvey Logistic was more accurate model for nondomestic consumption. A. Ahmad, in [15] categorized building electrical energy consumption forecasting methods into three categories namely, Engineering method, Statistical method, and Artificial Intelligence methods. Support Vector Machine SVM and Artificial Neural Networks ANN is a type of Artificial Intelligence techniques has a higher accuracy of results compared to statistical methods. However, Engineering methods has more complexity and difficulty on application which also has lack of inputs information. SVM is an ANN algorithm used in non-linear forecasting problems such as solving a time series problem. Hybrid model is a suggested model having the least errors than a single model, which also has been applied in many other electricity load forecasting studies by combining the models to have more performance results. A. Shrivastava, in [16], three different techniques of ANN were applied to forecast electricity load for one more hour in advance in Jabalpur region in India. Those techniques were namely radial bases function network, feed forward back propagation network, and cascade forward back propagation. The author also explained the difference between those three different techniques were the radial bases function network use radial bases function as an activation function in the network which has three layers (input, hidden, and output) layers. The feed forward back propagation network which is known the most techniques used for electricity load forecasting has one flow direction which never goes back starting from input layer to output layer where the errors are fed back to the pervious layer during training process. Cascade forward back propagation differs from feed forward back propagation network by the way of connection between the layers, where it could be connected for input layer to hidden layers to output layers, or from input layers to output layers directly. Results shows that all models used preforms well with high accuracy, however radial bases function network has the least MSE = 1.62 compared to feed forward back propagation network MSE = 1.7032e+004 and cascade forward back propagation MSE = 3.2392e+004.

3. METHODOLOGY

After Collecting historical electricity demand data from King Abdullah Petroleum Studies and Research Center, the data pattern for the regions were studied and all showed monthly seasonality with slight variations as per figure.1

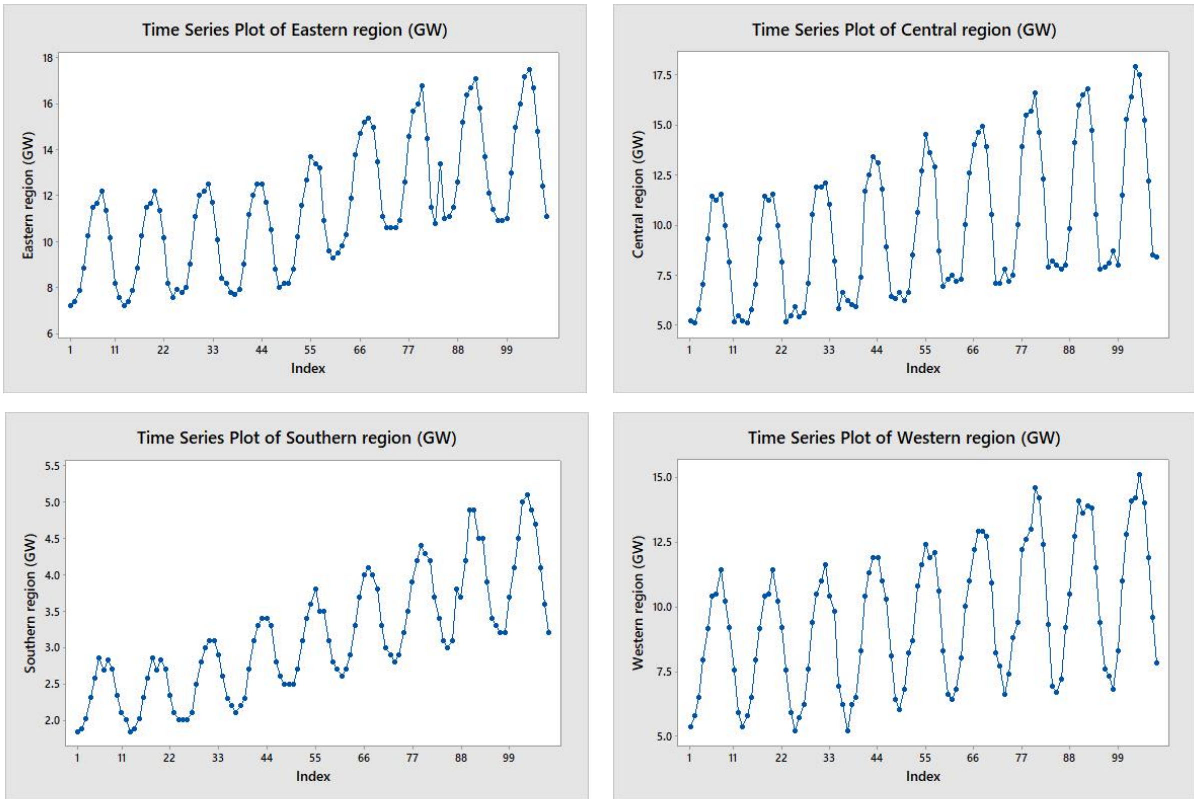


Figure.1 Time Series Plot for Regional Demand in Saudi Arabia

After that three forecasting methods were applied starting with the time series decomposition method with a multiplicative model, The Box-Jenkins methodology (ARIMA) which shown in Table.1 and Winter's triple smoothing method to find the forecast of electricity demand for each region. Then, those forecasts were combined to obtain the total demand of electricity for Saudi Arabia.

Table 1 Summary of Chosen ARIMA Models

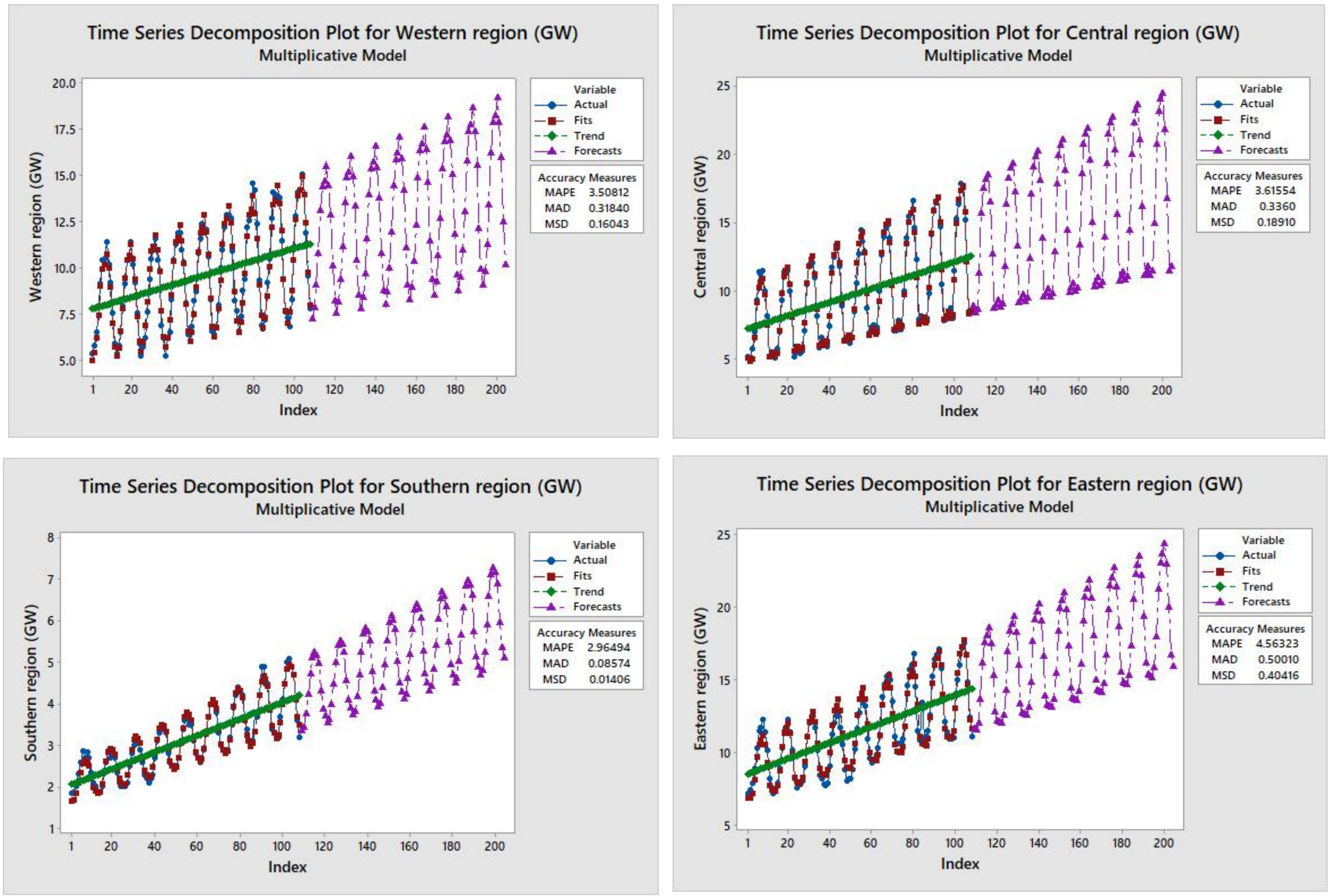
Region	ARIMA Model
West	(0,0,0)(2,1,0)12
Center	(0,0,0)(1,1,0)12
East	(0,0,0)(0,1,1)12
South	(0,0,0)(2,1,0)12

4. RESULTS

Forecasts for the next 96 periods from Jan. 2018 until Dec. 2025 were obtained for each region.

4.1 The Time Series Decomposition Method

After applying decomposition methodology with a Multiplicative Model, the results show that the demand continues to grow for all regions with a peak at summer season as shown in Figure.2. Figure.2



Forecasting Results for Saudi Arabia Regional Demand Using Decomposition

In addition, those forecasts were combined to achieve total demand of electricity for Saudi Arabia as shown in Figure.3, which shows that peak demand for period 92 in Aug 2025 will be 75.2672 GW.

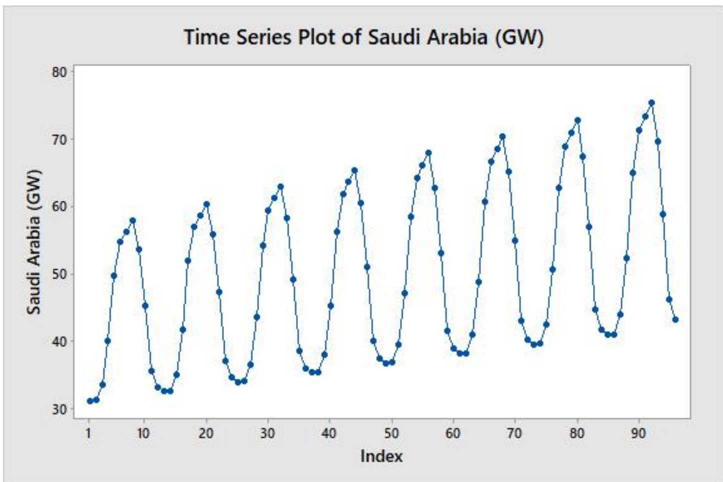


Figure. 3 Forecasting Results for Saudi Arabia Demand Using Decomposition

4.2 The Box-Jenkins (ARIMA) Method

After applying ARIMA methodology based on Table.1, models, the results show that the demand continues to grow for all regions with a peak at summer season as shown in Figure.4. However, after combination of models the total demand of electricity for Saudi Arabia as shown in Figure.5, shows that peak demand for period 92 in Aug 2025 will be 69.0350 GW.

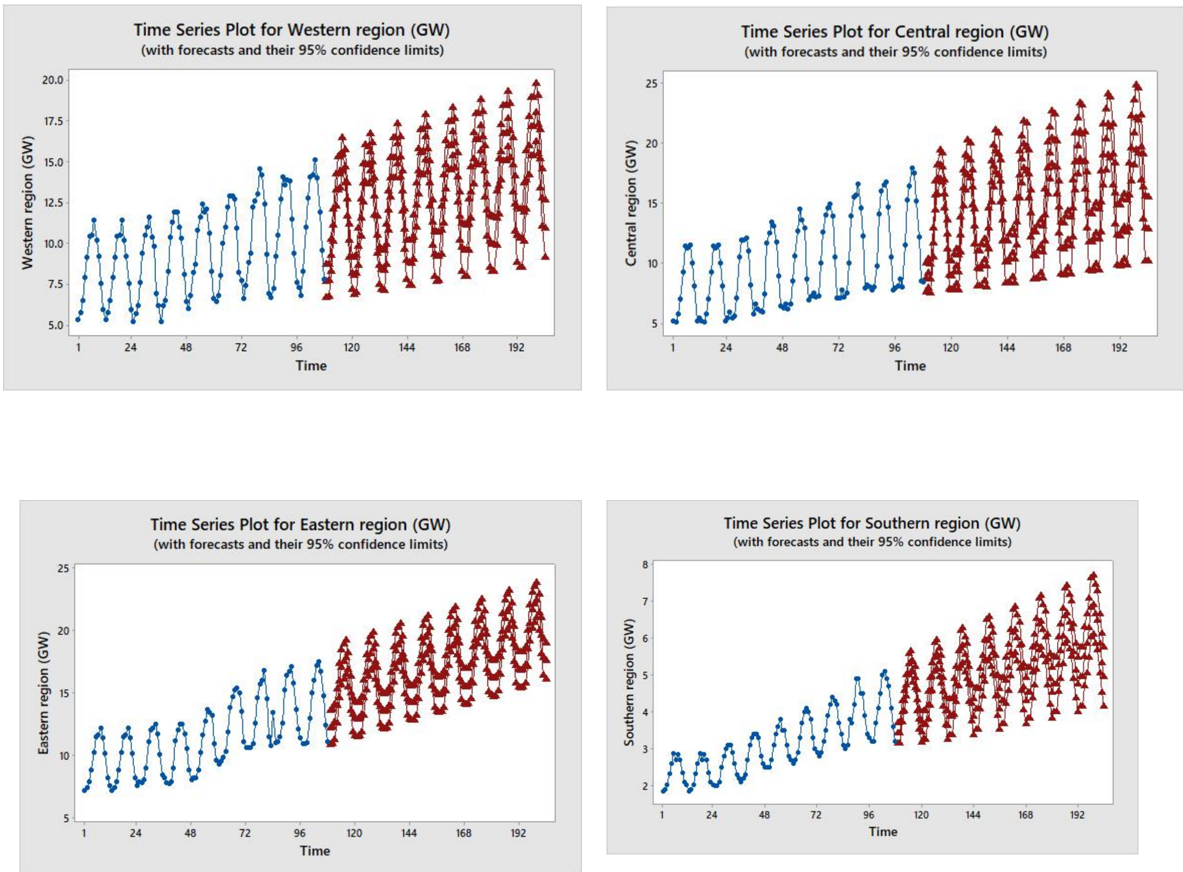


Figure.4 Forecasting Results for Saudi Arabia Regional Demand Using ARIMA Method

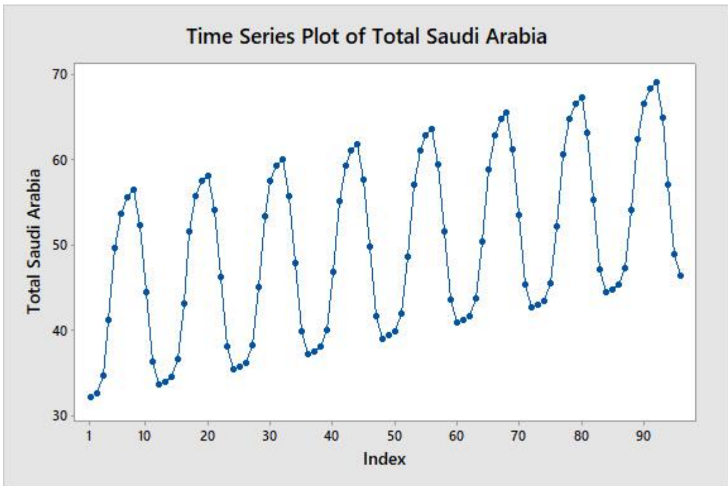


Figure.5 Forecasting Results for Saudi Arabia Regional Demand Using ARIMA Method

4.3 Winter's Triple Smoothing Method

After applying Winter's Triple Smoothing Method, the demand continues to grow for all regions with a peak at summer season as shown in Figure.6. However, after combination of models thee total demand of electricity for Saudi Arabia as shown in Figure.7, shows that peak demand for period 92 in Aug 2025 will be 60.7188GW.

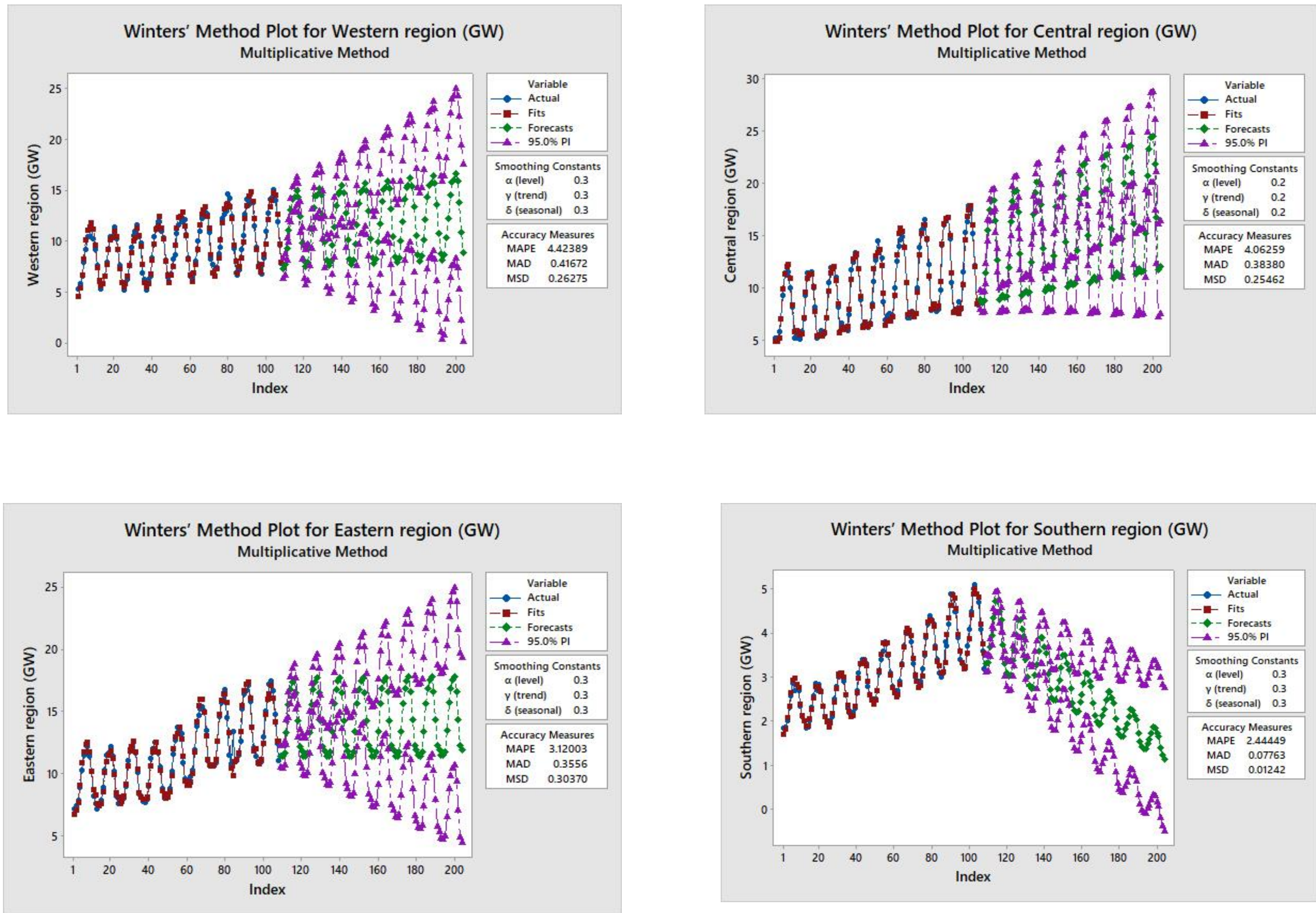


Figure.6 Forecasting Results for Saudi Arabia Regional Demand Using Winter's Triple Smoothing Method

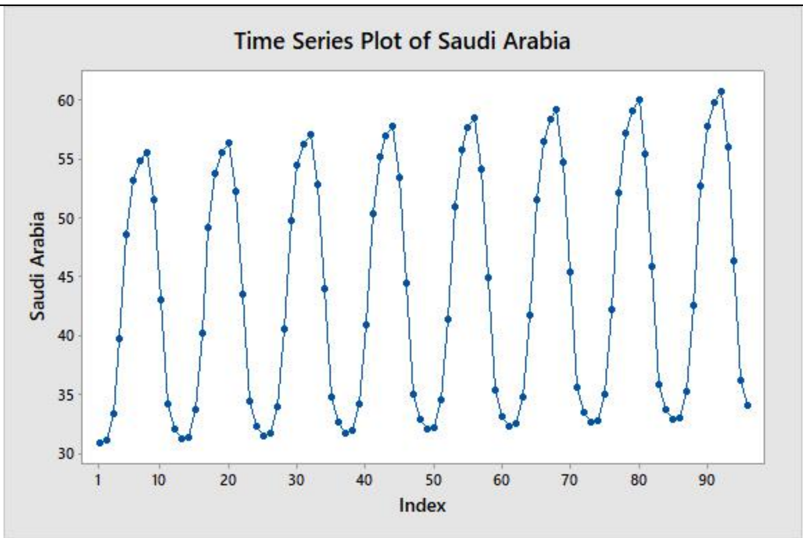


Figure 7 Winter's Method Forecasting for Saudi Arabia.

5. DISCUSSION

In this study, MSE where generated directly for each model using the Minitab results displayed in Table 2 below for each region and the average MSE representing MSE for Saudi Arabia forecasts, the time series decomposition method has the least errors with an average MSE = 0.191, compared to other methodologies.

Table 2 MSE Results for Electricity Demand Forecasting for All Regions

Model	**MSE**				
	Western	**Central**	**Eastern**	**Southern**	**Average**
Decomposition	0.16	0.19	0.40	0.014	0.191
ARIMA	0.260	0.37	0.49	0.02	0.285
Winter's	0.262	0.25	0.3	0.012	0.206
Best	Decomposition	Decomposition	Winter's	Winter's	

One way to minimize MSE when having a group of models is by combining those models which have the minimal errors. In this study, the model with least error for each region will be selected in the combined model. This will minimize the MSE from 0.191 to 0.165. The results for Total Saudi Arabia Forecast is shown in Figure.8, which shows peak demand in August 2025 will be 63.30115 GW.

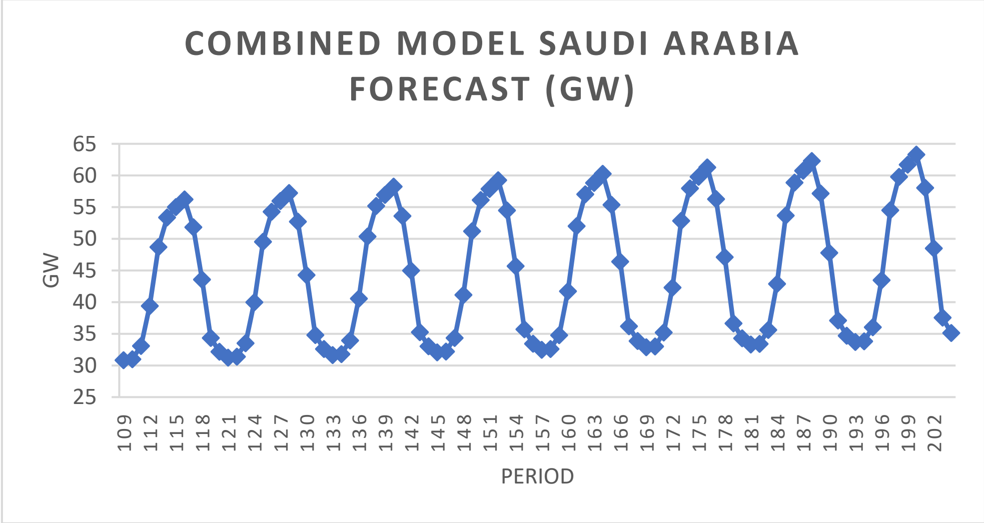


Figure 8 Combined Model Forecasting for Saudi Arabia.

Also, an analysis of electricity demand factors was also studied using fishbone and regression analysis to identify the most important factors affecting electricity demand in Saudi Arabia as shown in Figure.9, the top 5 factors is displayed in Table 3 below:

Table 3 Top Five Electricity Demand Factors in Saudi Arabia

Effect	R-sqr
Population	96.6%
Number of electricity subscribers	96.3%
Number of factories	94.3%
Co2 emissions	93.0%
Air Temperature	92.4%

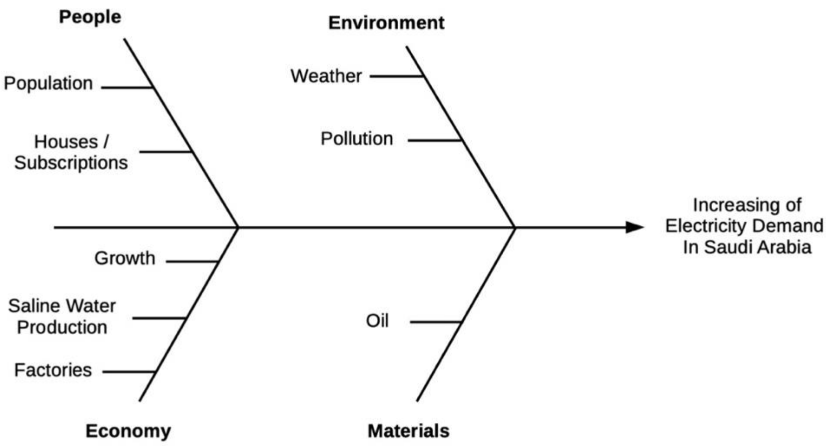


Figure.9 Cause and Effect Diagram

6. RECOMMENDATION

1- It is clear from Table 3 that the more population and subscribers are, the more demand will be on electricity, for that it is recommended to encourage subscribers to install solar cells in their houses which could help to produce a range of (150-370 watts/panel) depending on UV index, cell size, and technology [17]. Also, since they are more efficient in hot and sunny climate, It is recommended to install them in the deserts regions in parallel to the current power production.

2- focusing on the relationship between population, number of factories, CO_2 emissions, and air temperature. The higher factories are there, the more pollution and CO_2 is being produced, which affects directly Air temperature. A feasible solution to lower the effect from this problem are trees. Trees can cool down temperature by 5 to 8 degrees, by creating shades, absorb CO_2, and producing humidity through evaporation process, which will affect directly energy consumption [18]. Planting large numbers of trees could come through volunteering works in schools and during festivals activities periods.

3- In this master thesis three forecasting methods, namely Arima, Time Series Decomposition and Winter method were used to forecast electricity demand in Saudi Arabia till the year 2025. Other methods such as neural networks and qualitative methods can also be considered in future research.

Conflict of interest: The authors declare that they have no conflict of interest.

Ethical statement: The authors declare that they have followed ethical responsibilities

REFERENCES

[1] Yasmeen F., Sharif M., "Functional Time series (FTS) Forecasting of Electricity Consumption in Pakistan", International Journal of Computer Applications, Vol. 124, No.7, August (2015).

[2] Alshahrani J., Boait P., "Reducing High Energy Demand Associated with Air-Conditioning Needs in Saudi Arabia", energies, Vol. 12, No. 87, (2019).

[3] Federal Reserve Economic Data, Federal Reserve Bank of St. Louis Website, URL: *https://fred.stlouisfed.org/series/POPTTLSAA148NRUG*

[4] Available at: *https://en.wikipedia.org/wiki/Energy_in_Saudi_Arabia*

[5] Alrashed F., Asif M., "Trends in Residential Energy Consumption in Saudi Arabia with Particular Reference to the Eastern Province", Journal of Sustainable Development of Energy, Water and Environment Systems, Vol. 2 No. 4, (2014).

[6] Bogomolov, A., Lepri, B., Larcher, R. et al., "Energy consumption prediction using people dynamics derived from cellular network data", EPJ Data Sci. Vol. 5, No. 13, (2016).

[7] Perera F., "Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist", Int. J. Environ. Res. Public Health, Vol.15, No.16, (2018).

[8] Düren, M., "Understanding the Bigger Energy Picture", Springer, Giessen, Germany, (2017).

[9] Ren J., "Sustainability prioritization of energy storage technologies for promoting the development of renewable energy: A novel intuitionistic fuzzy combinative distance-based assessment approach", Renewable Energy, Vol. 121, Pages 666-676, (2018).

[10] Hu Y., "Electricity consumption prediction using a neural- network-based grey forecasting approach", Journal of the Operational Research Society, Vol. 68, Pages 1259–1264, (2017).

[11] Singh, Arunesh Kumar et al. "An Overview of Electricity Demand Forecasting Techniques." Network and Complex Systems, Vol. 3, Pages 38-48. (2013).

[12] Lee, Y.W., K.G. Tay, & Y.Y. Choy. "Forecasting Electricity Consumption Using Time Series Model." International Journal of Engineering & Technology [Online], Vol. 7, No.4.30, Pages 218-223, (2018).

[13] Ozturk S., Ozturk F., "FORECASTING ENERGY CONSUMPTION OF TURKEY BY ARIMA MODEL", Journal of Asian Scientific Research, Vol. 8, No. 2, Pages 52-60, (2018).

[14] Mohamed Z., Bodger P., "Forecasting electricity consumption in New Zealand using economic and demographic variables", Energy, Vol. 30, Issue 10, Pages 1833-1843, (2005).

[15] Ahmad A.S., Hassan M.Y. et al., "A review on applications of ANN and SVM for building electrical energy consumption forecasting", Renewable and Sustainable Energy Reviews, Vol 33, Pages 102-109, (2014).

[16] Shrivastava A., Bhandakkar A., "Power System Planning and Operation Using Artificial Neural Networks", International Journal Of Computational Engineering Research, Vol. 04, Issue 01, (2014).

[17] Available at: *https://us.sunpower.com/how-many-solar-panels-do-you-need-panel-size-and-output-factors*

[18] Available at: *https://science.howstuffworks.com/nature/climate-weather/storms/trees-affect-weather1.htm*

