https://doi.org/ 10.33472/AFJBS.6.9.2024.312-324

AFJBS

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Unveiling Tomorrow's Energy Demand - Enhancing Electricity Consumption Forecasts in Somalia with Linear Regression and Multilayer Perceptron (MLP) Neural Networks

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Article History

Volume 6,Issue 9, 2024

Received:14Mar 2024

Accepted : 09 Apr 2024

doi: 10.33472/AFJBS.6.9.2024.312-324

Abstract

Numerous benefits can be derived from forecasting electrical energy consumption, encompassing both economic and environmental aspects. Efficient resource utilization to meet the current demand, reduced production costs, and minimized CO_2 emissions are among the advantages. Additionally, accurate prediction facilitates the development of effective power supply strategies, enables financial planning, supports marketing research, and paves the way for the integration of renewable or alternative energy sources in the near future. Over the period from 2000 to 2021, Somalia witnessed a remarkable annual growth rate of 61% in electricity consumption. This trend is expected to persistently drive the demand for power. In this study, various techniques such as Linear Regression (LR), Gaussian Processes Regression (GPR), Multi-Layer Perceptron (MLP), and Sequential Minimal Optimization Regression (SMOreg) were employed to predict future electricity consumption in Somalia. Inputs for the estimation model included Somalia's Gross Domestic Product (GDP), population, and historical electrical consumption data spanning from 2000 to 2023. By utilizing the regression algorithms provided by the open-source WEKA program, a forecast was generated for Somalia's projected electrical energy consumption from 2024 to 2030. The findings reveal an upward trend in the amount of electricity consumed at present, as demonstrated by all four models.

Keywords: Electricity consumption; artificial neural networks; Somalia; Multiple regression analysis.

Introduction

The electricity crisis in Somalia presents significant challenges in ensuring a stable and reliable power supply for the population. This issue is marked by recurrent power outages, limited access to electricity in numerous regions, elevated energy costs, and reliance on environmentally unsustainable sources. Approximately 40% of the national population is reported to have access to electricity [1].

The Ministry of Energy and Water Resources is planning the Somali Electricity Sector Recovery Project, which aims to achieve two primary goals. Firstly, it seeks to enhance access to more affordable and environmentally friendly electricity in the designated project regions. Secondly, it aims to revive and restore the electricity supply industry [2].

Forecasting the amount of electricity consumed could provide numerous benefits, both in terms of economic and environmental advantages. It would ensure the efficient utilization of resources to fulfill the current demand, minimizing costs and CO_2 emissions associated with the production process. Moreover, accurate prediction facilitates the formulation of power supply strategies, financial planning, marketing research, and the implementation of renewable or alternative energy sources in the foreseeable future.[3]

From 2000 to 2021, Somalia experienced an annual electricity consumption growth rate of 61%. And it is expected to continue the increase in electricity consumption. [4]. Forecasting long-term consumption of electricity for a period over 5 or 10 years is an essential requirement in national electricity system planning.[3]. Figure 1 illustrates electricity consumption in Somalia from 2000 to 2021. [4].

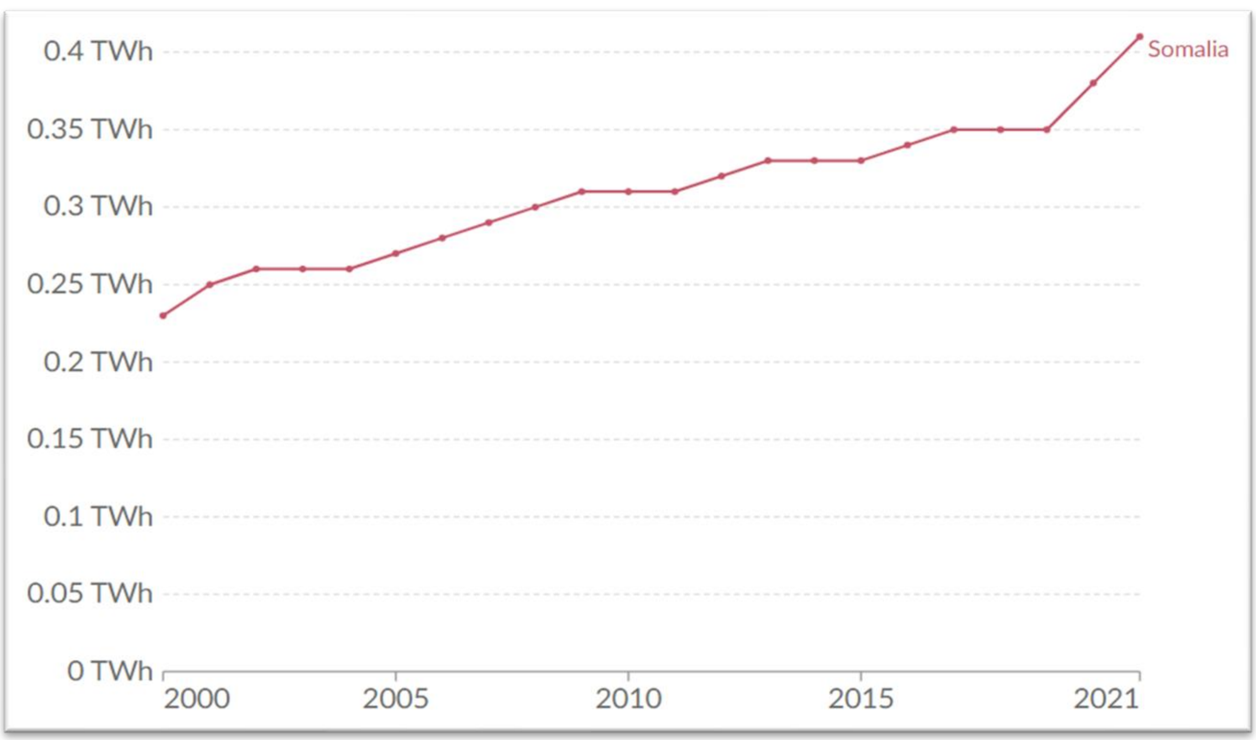

Figure 1: electricity consumption in Somalia from 2000 to 2021 [4]

A significant challenge in creating reliable forecasts lies in ascertaining an adequate and relevant data set for accurate prediction. Insufficient data levels inevitably lead to subpar forecasting outcomes. [5] Underestimating demand could lead to potentially catastrophic outages, impacting both the economy and people's lives. Overestimation, on the other hand, could lead to unnecessary idle capacity and wasted money. [6]. Depending on the current market situation, country or supplier-specific electricity forecast models are created. Each nation has a unique consumption model adapted to its particular circumstances.[7][8].

The fact that electricity is difficult to store once generated is one of its particular challenges. Forecasting energy consumption is also challenging due to the irregularities and internal complexities of many interrelated factors, including GDP, energy imports and exports, industrial production, technological progress, population and employment.[3] An important factor closely related to energy consumption is the total population. Economic indicators such as GDP, employment and inflation are often also taken into account. People's lifestyles are becoming increasingly dependent on energy-consuming devices and appliances as their living standards and per capita GDP increase. Therefore, accurate forecasting of future energy and electricity consumption is crucial for sensible future planning, investing in new power generation facilities and maintaining the balance between energy supply and demand.[8].

Various techniques are commonly used when forecasting electricity consumption. These include soft computing techniques such as artificial intelligence, fuzzy logic and genetic algorithms, as well as traditional methods such as time series analysis, econometric models and regression. New approaches to power demand modeling include support vector regression, ant colony optimization, and particle swarm optimization. A model put into practice should also make future computations easier.[9][8][7].

Vincenzo Bianco et al. [6] forecasted the electricity consumption in Italy using linear regression models. He developed various regression models using historical electricity consumption data, gross domestic product (GDP), gross domestic product per capita (GDP per capita), and population data from the period between 1970 and 2007. Fazil Kaytez et al.[7] conducted a study comparing different methods of forecasting techniques to forecast electricity consumption in Turkiye. They compared least squares support vector machines (LS-SVM) and linear regression method and, artificial neural networks technique. In their study, a historical data from 1970 to 2009 is employed to define the independent variables such as gross electricity generation, installed capacity, total subscriber count, and population within the models. The results of the forecasts are then compared against one another using a range of performance indicators. Vu H. M. Nguyen et al. [3] in their paper sets out to predict the electricity consumption of Vietnam's power system (measured in GWh) through to the year 2030. It utilizes an econometric model based on the Cobb-Douglas production function. The forecasting model incorporates five key variables: GDP, income, population, the share of industry and services in GDP, and the total number of households. Daniel Mburamatare et al. [10] conducted a study Investigating and Predicting Power Usage in Rwanda's Energy-Demanding Industries. Their study utilizes both multiple regression (MLR) and autoregressive integrated moving average (ARIMA) methods for its econometric evaluation. MLR is applied to examine the effects of various economic factors on electricity consumption within high-energy industries. Meanwhile, ARIMA is employed to forecast electricity consumption from 2000 to 2026. There are many other studies utilizing different techniques such as [11], [12], [13], [8], [14] and more. In this paper, the electricity consumption for Somalia between 2023 and 2030 will be forecasted, using linear regression, a multilayer perceptron neural network approach and prediction algorithms found in the WEKA program, based on GDP, population, and annual electricity consumption data from 2000 to 2021.

Material and Method

1. Regression analysis

Regression analysis is a method utilized to analyze and model data that is numerical in nature. It is an analysis of the values of one or more variables that are independent in relation to the values of a dependent variable [13]

A linear regression model is employed to forecast the consumption of electricity, considering the time series data of GDP and population.

The model that is being suggested for this study is as follows.

$$y_c = a + b_1 x_1 + b_2 x_2 + \mathrm{u}$$

$\mathrm{y_c}$ is the Dependent variable in this case the Electricity consumption measured in gigawatt-hours (GWh).

a is Constant parameter of the model

b_1 and b_2 are the Coefficients of independent variables

u is the error/disturbance term.

x_1 is the independent variable 1 here is the population in millions and x_2 is the independent variable 2 here is the GDP in USD.

The error term denotes unexplained fluctuation in the dependent variable and is considered as a random variable. The parameters such as Population and Gross Domestic Product (GDP) per capita are estimated to provide the most accurate representation of the data.

2. Artificial Neural Network

Forecasting electricity consumption using Artificial Intelligence, specifically through Artificial Neural Networks (ANNs), represents a significant advancement over traditional forecasting methods. ANNs are designed to handle complex problems by learning from provided data examples, thereby establishing an input-output mapping to perform accurate estimations. Central to this approach is the use of neurons, which are interconnected to form a network. While the literature acknowledges various network configurations, this particular study emphasizes the Multi-Layer Perceptron (MLP) model.[7][15][16] The Multi-Layer Perceptron (MLP) is a type of feedforward artificial neural network that consists of at least three layers of nodes: an input layer, one or more hidden layers, and an output layer. Each node, or artificial neuron, in one layer connects with a certain weight to every node in the following layer. The behavior of the network is defined by the weights between nodes, the activation function applied at each node, and the architecture of the connections as shown in fig. 2.

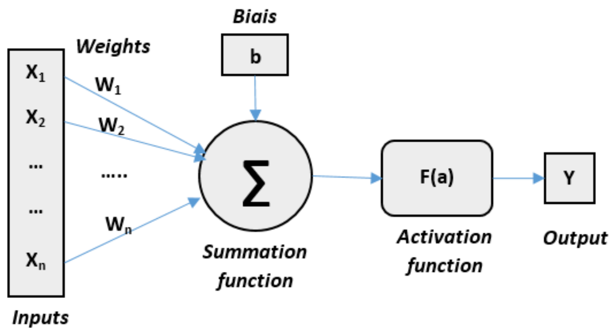

Fig 2 Multi-Layer Perceptron feedforward

Assuming a single output neuron for predicting Electricity Consumption (E), and using the outputs of the hidden layer (h_j), the output is calculated by summing the products of the hidden layer outputs and their corresponding weights, adding a bias, and applying an activation function g:

$$E = g\left(\sum_j v_j\, h_j + c\right)$$

where:

v_j and h_j are the weights from hidden neuron j to the output neuron,

c is the bias for the output neuron,

g is the activation function for the output layer, which could potentially be different from f.

This MLP model structure allows for the prediction of Electricity Consumption based on the inputs Population and GDP by capturing complex, non-linear relationships through the hidden layer(s) and their activation functions.

3. Data collection

The study utilizes GDP and population as the independent variables. The variable being measured is the consumption of electricity. Table 1 displays the numerical values of these variables spanning the years 2000 to 2020.

Table 1: Data on Independent Variables and Electricity Consumption (2000-2023)

Year	Electric consumption GWh	Population	Gross Domestic Product (GDP) USD
2000	235	8872250	391.310
2001	245	9186719	248.364
2002	258	9501335	232.989
2003	273	9815412	290.699
2004	263	10130251	381.482
2005	273	10446856	447.417
2006	282	10763904	466.088
2007	292	11080122	488.457
2008	301	11397188	516.705
2009	305	11717691	251.371

2010	307	12043886	223.488
2011	310	12376305	237.868
2012	324	12715487	324.887
2013	334	13063711	382.808
2014	334	13423571	436.360
2015	335	13797204	481.521
2016	342	14185635	517.112
2017	350	14589165	555.159
2018	354	15008225	537.146
2019	358	15442906	589.439
2020	380	15893222	556.570
2021	410	16537016	576.541
2022	425	17597511	592.129
2023	440	18143378	622.129

The data were acquired from several sources. The Gross Domestic Product (GDP) data was sourced from the website http://data.un.org. [17]. The population data was acquired from the website https://www.worldometers.info [18]. The electricity consumption figures are sourced from the website https://ourworldindata.org [19].

4. WEKA software

WEKA is a software application for data mining and machine learning that was created by the University of Waikato in New Zealand. The name WEKA is derived from the acronym of the phrase "The Waikato Environment for Knowledge Analysis." The WEKA program was created using Java, which is a prominent object-oriented programming language. Weka is a software package that includes a range of visualization tools and algorithms designed for data analysis and forecasting. It also provides user-friendly graphical interfaces to facilitate easy utilization of these capabilities [20]. The interface of the WEKA program is depicted in the Figure.

Fig. 3: The interface of the WEKA program

Figure 1 displays the presence of 5 fundamental applications inside the WEKA program. The package includes five components: Explorer, Experimenter, Knowledge Flow, Workbench, and Simple CLI. The study utilized the Explorer interface. During the selection process for the data mining prediction algorithms in WEKA, we chose four methods to compare. We considered their popularity and previous studies in the literature before applying them to our dataset. The techniques mentioned are Linear Regression (LR), Gaussian Processes Regression (GPR), a Multi-Layer Perceptron (MLP) and Sequential Minimal Optimization Regression (SMOreg).

Findings and analysis

The study will employ the following analytical technique. In order to evaluate the regression techniques, a model was created utilizing the dataset spanning from 2000 to 2020. This model was then applied to estimate the electrical energy consumption for the years 2022 and 2023, as presented in Table 2.

Year	LR	MLP	GPR	SMOreg
2022 forecasted value	424.8669	420.2773	428.6239	426.5109
2023 forecasted value	434.5349	424.3747	440.2189	436.0573
2022 Actual value	425			
2023 Actual value	440			

The created model was tested (with MAPE values) by comparing the forecasted values with the actual values. Then, a new model was created using the data set between 2000 and 2023, and the years 2024 - 2030 were predicted using the new model created.

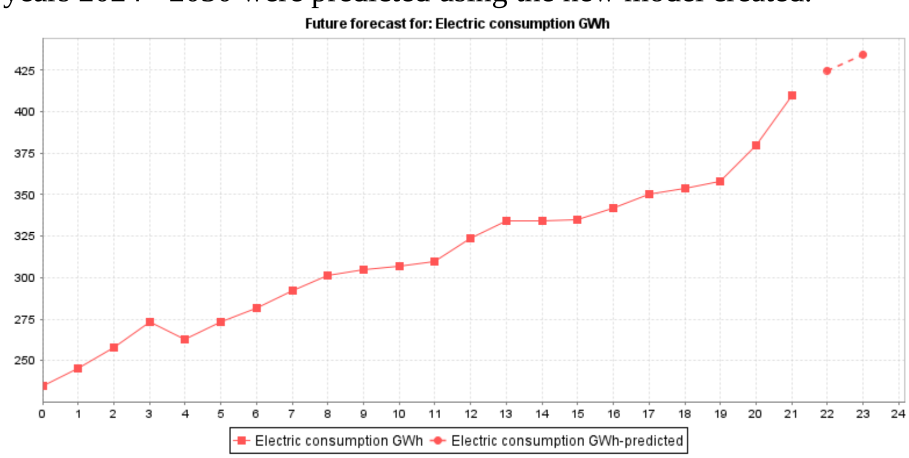

Fig. 4: Linear regression forecasting

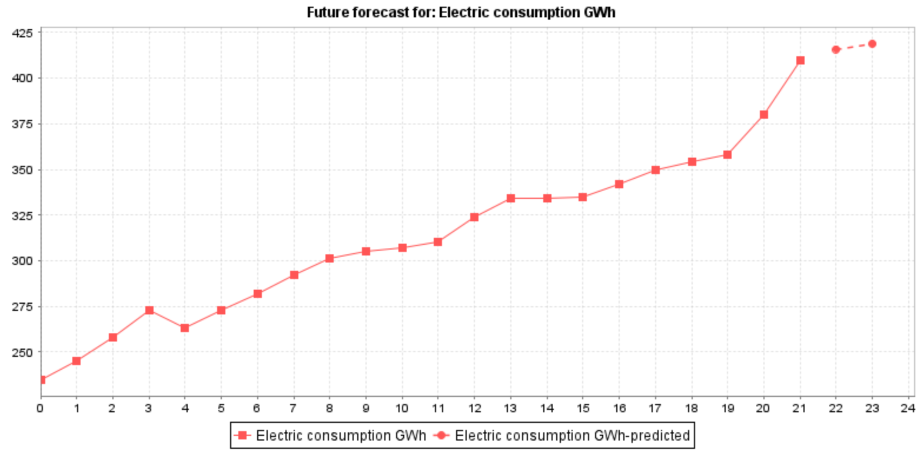

Fig. 5: Multi-Layer Perceptron forecasting

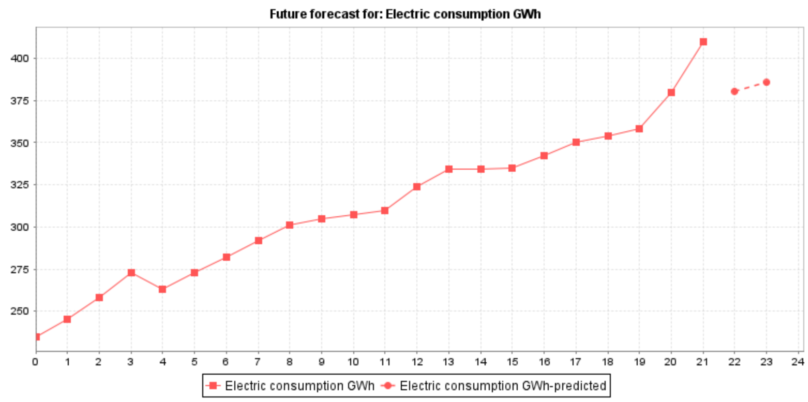

Fig. 6: Gaussian Processes Regression forecasting

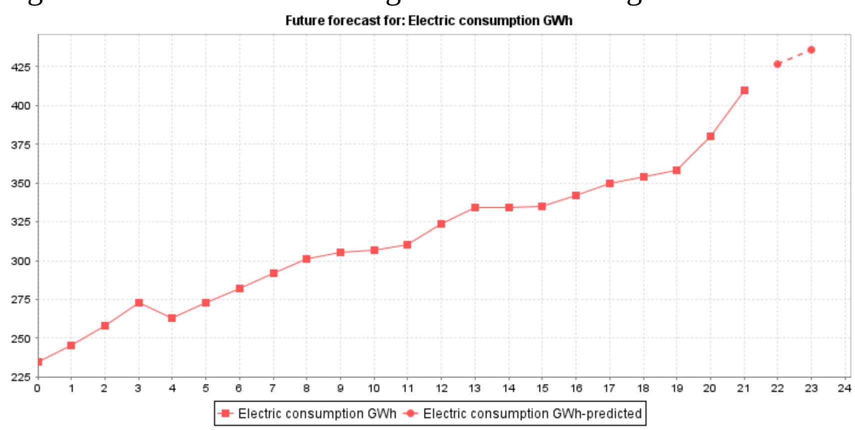

Fig. 7: Sequential Minimal Optimization Regression forecasting

Assessment of Performance using Mean Absolute Percentage Error (MAPE)

The MAPE approach was employed to assess the forecasting performance in this study. The Mean Absolute Percentage Error (MAPE) is mathematically described by the following equation:

$$\text{MAPE (\%)} = \left|\frac{Actual\ value - forecasted\ value}{Actual\ value}\right| \times 100$$

Table 3: Calculated MAPE values for 2022-2023

Year	**LR**	**MLP**	**GPR**	**SMOreg**
2022 MAPE (%)	0.0313	1.1112	0.8526	0.3555
2023 MAPE (%)	1.2420	3.5512	0.0497	0.8960
Average MAPE (%)	0.6366	2.3312	0.4512	0.2702

The Linear regression algorithm yields the best result with 0.0313% when we look at the 2022 MAPE values shown in Table 3, and the Gaussian Processes Regression algorithm yields the best result with 0.0497% when we look at the 2023 MAPE values. The optimal value, reached in the SMOreg algorithm with 0.2702%, is evident when we examine the average MAPE values for the years 2022-2023.

A comprehensive model was developed by implementing the aforementioned procedures on the complete dataset spanning from 2000 to 2023. Utilizing this novel model, the projected values for the years 2024 to 2030 were predicted and presented in Table 4.

Table 4 displays the predicted electrical energy consumption data for the years 2019-2023, which was calculated using the WEKA program.

Year	**LR (GWh)**	**MLP (GWh)**	**GPR (GWh)**	**SMOreg (GWh)**
2024	457.1184	449.0902	459.7946	456.2826
2025	474.0482	458.459	473.2961	470.2218
2026	490.742	466.4566	485.3059	482.1007
2027	506.1025	474.4102	498.1509	494.5411
2028	521.1305	481.7505	510.6842	506.3172
2029	536.1247	488.87	523.7694	518.4653
2030	551.6155	495.692	537.1473	530.829

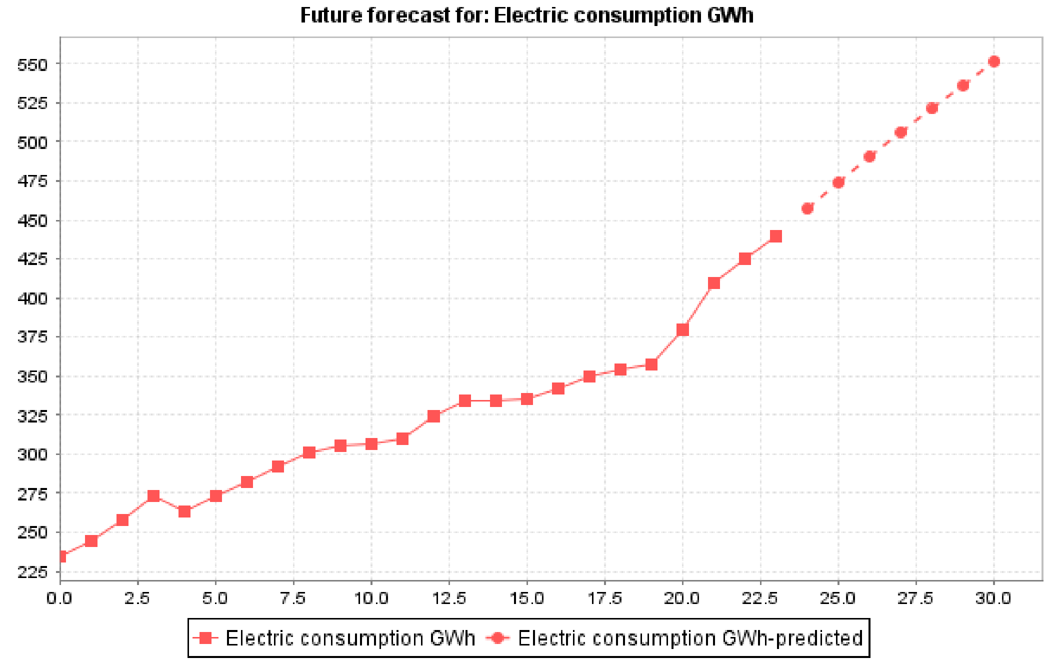

Fig. 8: Linear regression forecasting between 2024 to 2030

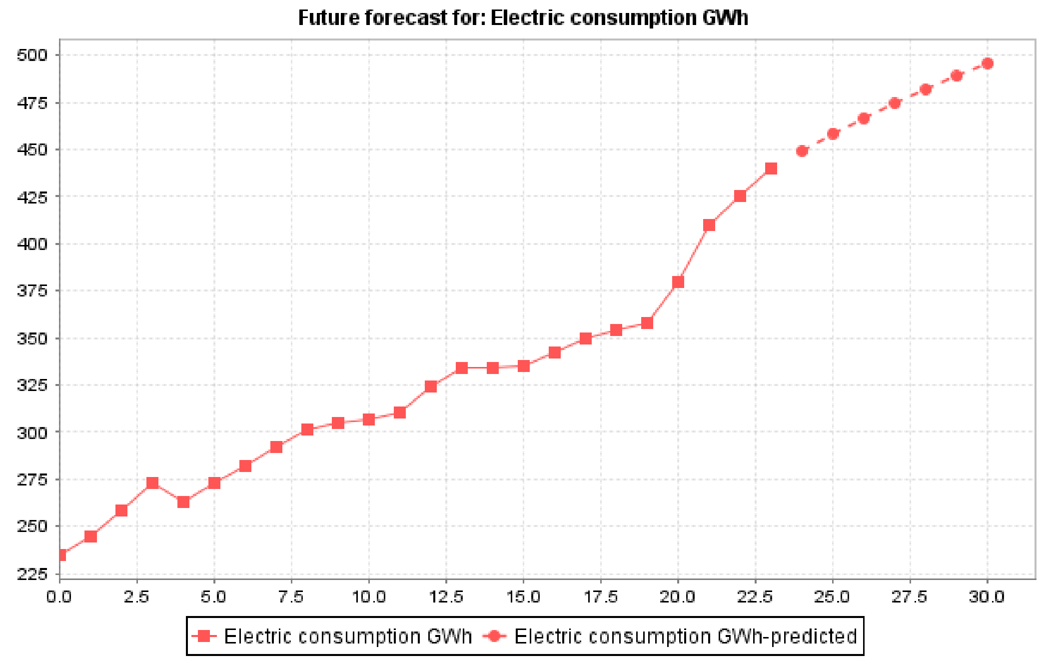

Fig. 9: Multi-Layer Perceptron forecasting between 2024 to 2030

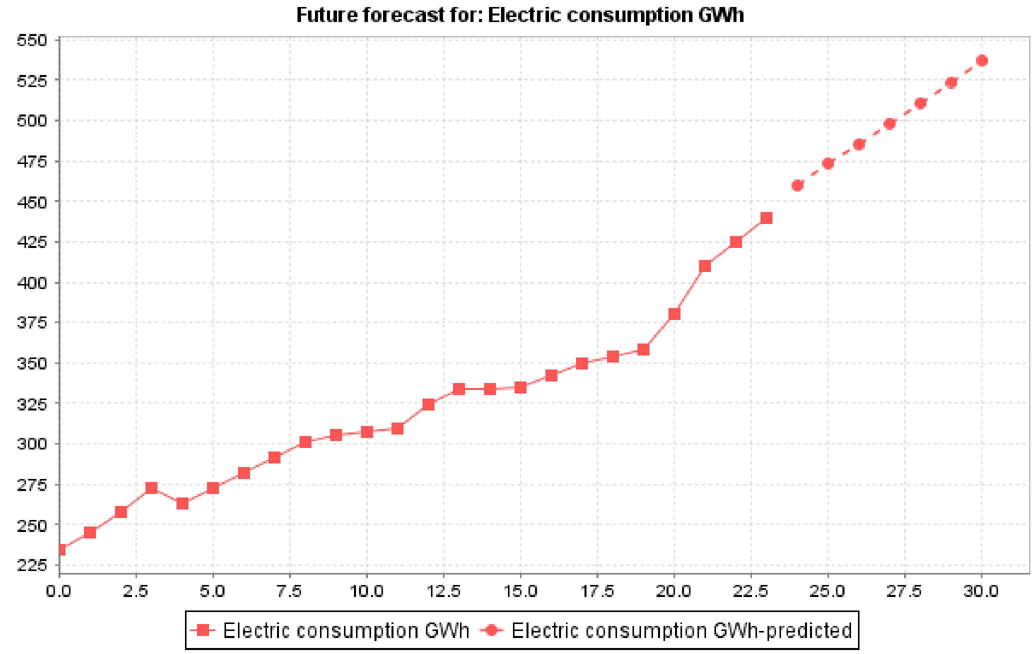

Fig. 10: Gaussian Processes Regression forecasting between 2024 to 2030

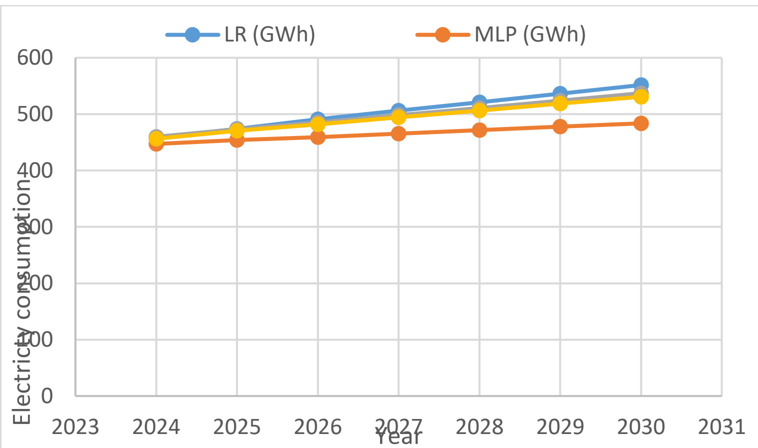

Figure 11: 2024-2030 electrical energy consumption graph estimated with 4 different regression algorithms

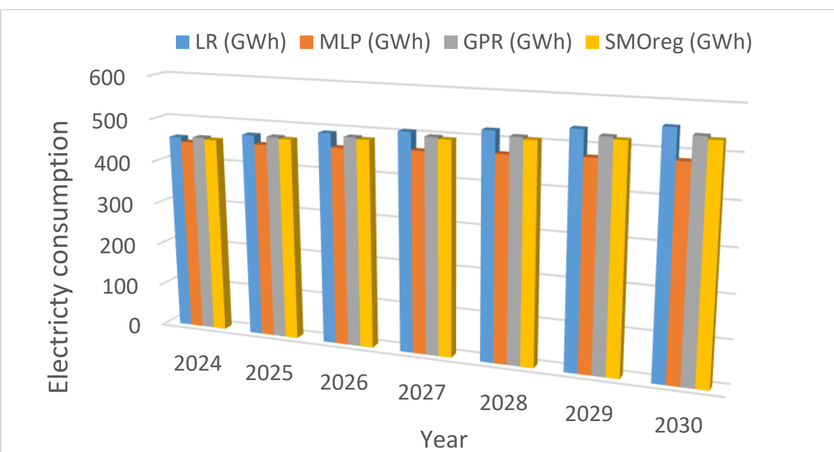

Figure 12: 2024-2030 electrical energy consumption graph estimated with 4 different regression algorithms

Examining the graphical data presented in Table 4 and Figure 8, which depict the projected consumption of electricity for Somalia from 2024 to 2030; The LR regression algorithm predicted an electricity consumption of 457.1184 GWh for 2024 and 551.6155 GWh for 2030. The GPR regression algorithm estimated 459.7946 GWh for 2024 and 537.1473 GWh for 2030. The SMOreg regression algorithm predicted 456.2826 GWh for 2024 and 530.829 GWh for 2030. Lastly the MLP regression algorithm estimated 447.1848 GWh for 2024 and 483.6561 GWh for 2030. The open-source WEKA program was utilized in the study using four different algorithms.

ACKNOWLEDGMENT

The authors acknowledge financial support from SIMAD University's Centre for Research and Development (CRD). Additionally, the authors thank all participants.

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