Forecasting Electricity Consumption in Algeria Using Artificial Neural Networks

Sidi Mohammed Chekouri [1*], Abdelkader Sahed [2]

[1] University Centre of Maghnia (Algeria)
[2] University Centre of Maghnia (Algeria)

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Abstract:

This paper applied the artificial neural network (ANN) to forecast electricity consumption in Algeria. Two independent variables, GDP (Gross Domestic Product) per capita and population, are used to forecast electricity consumption. The models' performance is evaluated using the coefficient of determination (R2) and the mean absolute percentage error (MAPE). The results show that the ANN model that models electricity consumption as a function of economic indicators outperforms the ANN time input model. In addition, the results indicate that Algeria's projected electricity consumption will be 76.06 and 94.66 billion Kwh in 2020 and 2025, respectively. As a result, improved electricity forecasting is critical for policymakers when constructing future energy plants.

Keywords: Electricity Consumption; Forecasting; Artificial Neural Networks; Algeria

JEL Classification: Q47,C45,D12

[*] **Corresponding author, e-mail**: *Cheksidimed@yahoo.fr*

I- Introduction:

Electric energy plays an increasingly important role in terms of economical and social progress. The crucial role of electricity as an essential component of any country's development process has led to huge increasing demand for electricity and energy in the world.

Algeria has made huge efforts to develop its electricity and gas infrastructures, and to promote electricity access to its people. According to the World Bank access to electricity in Algeria was reported at 100 percent in 2018 (World Bank, 2020).

Algeria's electricity consumption has risen significantly in recent years. Between 2010 and 2016 electricity consumption rose from 33.84 billion kwh to 55.95 billion kwh, this means that the country has seen an increase of 65 percent in less than decade (Figure 1). This strong demand for electricity is driven by a rapid increase in the population growth, higher demand from households and the transport sector, and a heavily subsidized electricity prices.

In Algeria the main source of electricity generation is natural gas due to its availability and low cost. In 2016, more than 96 percent of electricity is generated with natural gas, while electricity from hydroelectric sources has recorded less than 1 percent in the same year (Figure 1). Algeria's government has developed a renewable energy program (The National Program for the Development of Renewable Energies), to diversify its energy mix, and increase the share of electricity generated by renewable sources. This program aimed to achieve a share of 27 percent of renewable energy sources in electricity production by 2030, equivalent of 22000 MW, of which 12000 MW for the domestic market, and 10000 MW for export to Europe (Table 1). Moreover, if the capacity target of this program will be achieved, this will allow Algeria to save 300 billion m3 of natural gas consumption by 2030 (IEA, International Energy Agency).

To implement an energy planning such as the NPDRE it is primarily importance to policy makers to analyse the future evolution of electricity demand. Algerian government is making concerted efforts to start a new renewable energy development plan (The National Program for the Development of Renewable Energies). This program is focused on developing and expanding the use of renewable resources in the production of electricity. The new plan aims to achieve 27 percent renewable energy in total electricity generation by 2030.Therefore, the objective of this paper is to analyse and forecast Algeria's electricity consumption. Two models were built to predict electricity consumption in Algeria using Artificial Neural Networks (ANN). In recent years artificial neural networks (ANNs) have gained much importance among researchers. This is mainly because neural networks model linear and nonlinear relationships among variables (Scarborough and Somers, 2006).

The rest of this paper is organized as follows. section two presents the literature review. A brief description of the Artificial Neural Networks is presented in section three. Section four details the data. Section five discusses the empirical results and forecasts electricity consumption until 2025. Section six concludes.

1- Literature Review :

There are several previous studies available in the literature that have attempted to model electricity demand for developing countries. Different methods have been employed to model and forecast electricity demand. Overall, these methods are divided into two broad categories: ***i)*** Parametric methods (traditional econometric) such as autoregressive moving average, exponential smoothing, multiple regression models, co-integration and the error correction model (ECM) and the auto regressive distributed lag method (ARDL). See for example the studies of Eltony and Mohammad (1993), Eltony (1995), Abdel Aal and Garni (1996), Al-Sahlawi (1999), Al-Faris (2002), Eltony and Al-Awadhi (2007) and Atalla and Hunt (2016) for the Middle East countries, Pourazarm and Cooray (2013) for Iran, and Hasanov, Hunt and Mikayilov (2016) for Azerbaijan. ***ii)*** Artificial intelligence methods such as neural networks, fuzzy linear regression, fuzzy logic systems and genetic algorithms. See for example the studies of Azadeh, Ghaderi and Gitiforouz (2006); Ghomi, Moeti and Azimi (2011); Sarkar, Rabbani, Khan and Hossain (2015); and Saravanan, Nithya, Kannan, and Thangaraj (2014).

For Algeria, previous empirical studies on electricity demand modeling are limited despite the central role of demand for electricity to the economy and the controversies about the policy of energy subsidies (see for example: Bouznit and al., 2018). The present study employs neural network model method for modeling and forecasting electricity demand in Algeria.

Therefore, given the focus of the present study on artificial intelligence methods in modeling Algerian electricity demand, this section briefly reviews some selected previous studies that have used these methods particularly ANN to model electricity demand for developing countries.

In the literature traditional methods such econometric models are being widely used for electricity demand modeling and forecasting. The use of the artificial intelligence methods is becoming more increasingly popular modeling techniques to estimate and forecast electricity consumption mainly because of their flexibility and explanation capabilities (Kucukali and Baris, 2010).

During the past decades, the application of fuzzy regression and artificial neural network methods for electricity modeling has been used in several studies. Azadeh, Ghaderi and Gitiforouz (2006) have used fuzzy linear regression technique to estimate electricity demand function in residential sector in Iran. In their study the demand for electricity has been modeled as a function of electricity price (PR), number of residential customers (NC) and gross residential customer’s income (IN). They found that electricity consumption is positively associated with (NC) and negatively with (PR). In another study, Azadeh, Saberi and Gitiforouz (2013) used an integrated algorithm based on fuzzy regression, time series and principal component analysis for forecasting electricity consumption in Iran. Their results showed that the selected fuzzy regression model gave better estimated values than time series model for electricity demand forecasting. Sarkar, Rabbani, Khan and Hossain (2015) predicted the electricity demand in Bangladesh from 2015 to 2020, using fuzzy linear regression method. The authors used average annual temperature and number of annual consumer variables to estimate future electricity demand. They employed mean absolute percentage error (MAPE) criteria to measure the forecast accuracy. Saravanan, Nithya, Kannan, and Thangaraj (2014) employed fuzzy logic to predict India’s electricity demand until 2026 using data from 1975 to 2010. In their study GDP per capita, population, import and export are taken as independent variables and electricity demand is the predicted variable. The study showed that fuzzy approach gave better forecasting performance. Kucukali and Baris (2010) developed fuzzy logic model to forecast short term gross electricity demand of Turkey. They found that the proposed model made good performance prediction. The fuzzy model average absolute relative errors (AREP) were 4.1 percent, which is less than practically accepted 10 percent.

During the past decades, the application of artificial neural network methods for electricity modeling has been used in several studies. Nizami and El-Garni (1995) developed an artificial neural network model for forecasting electric energy consumption in the eastern province of Saudi Arabia. The authors used weather data (temperature and humidity), global solar radiation, and population as inputs of the neural network, while the output was the electric energy consumption. Their results showed that the proposed neural network model predicted the electric energy consumption better than the regression model. Kavaklioglu, Ceylan, Ozturk and Canyurt (2009) predicted electricity consumption of Turkey using artificial neural networks for the variables population, gross national income, imports, exports and total electricity consumption. Kargar and Charsoghi (2014) proposed a neural network model to predict annual electricity consumption in Iran. In Charsoghi (2014)'s study, time series ARIMA method has been used to investigate the accuracy of the proposed neural network method. The presented results indicated that predicting with neural network is more accurate.

Ghomi, Moeti and Azimi (2011) Used Fuzzy Regression Method and Artificial Neural Network for forecasting electrical energy load in Iran. Their results showed that the ANN is better in comparison with fuzzy regression technique. Kaytez, Taplamacioglu, Cam, and Hardalac (2015) compared the accuracy in predicting long term electricity consumption in Turkey among three different approaches: regression analysis, neural networks and least squares support vector machines. They found that the LS-SVM model perform better than other models.

As far as we are aware, the literature on electricity demand modeling and forecasting in Algeria is limited. The only investigation of electricity demand for Algeria has been conducted by Bouznit and al. (2018). Their study estimated a residential electricity consumption per capita demand function for Algeria over the period 1970-2013, by using an extended Autoregressive Distributed Lag model (ARDL). The authors chose five independent variables which are GDP per capita, its squared and cubed terms, the electricity prices, and the goods and services imports to estimate electricity demand function. They found that the coefficient related to GDP per capita is positive and significant, while that of electricity prices is negative and statistically significant. Additionally, their results showed that electricity demand is inelastic with respect to electricity price. However, the above econometric technique adopted in the study of Bouznit and al. (2018) cannot account for possible nonlinear relationships among variables. In view of this, our study contributes to Algeria's electricity consumption literature, by proposing an artificial neural network (ANN) model to predict future electricity consumption, since ANN is more appropriate for dealing with nonlinear data.

II– Methods and Materials:

1- Artificial Neural Networks model:

Artificial Neural Network (ANN) are a computational models designed to mimic human brain functioning. Basically, the architecture of an artificial neural network consists of three or more layers, called the input layer, hidden layer, and output layer (Figure 2).

The artificial neural network relationship between the inputs and the outputs has the following mathematical relationship:

$$y_j = f\left[\sum_i (w_{ij} x_i)\right] \quad \text{...(1)}$$

Where: x_i denotes the inputs to the neurons, as $1 \le i \le n$. w_{ij} : denotes the connection weights (also called parameters) between neurons. y_j is the output of the neuron. f is the transfer function. Generally, the summation of the weighted inputs is passed through a nonlinear function called the transfer function or activation function. The widely used transfer functions in the neural network are the sigmoidal and the tanget hyperbolic functions. The multi-layer perceptron (MLP) trained with back propagation algorithm is one of the most commonly used to train neural networks and is widely used in the time series forecasting (Kaastra and Boyd, 1996). The advantage of the MLP network consists of their ability to learn complex relationship between input and output vectors better than conventional methods (Lee and Park, 1992). Moreover, it is proved that ANNs are able to give better performance in dealing with the nonlinear relationships among variables (Saravanan, Kannan and Thangaraj, 2012). In ANN weights are the most important factors in converting an input to impact the output. The determination of best set weights is achieved through training the network. The multi-layer perceptron (MLP) trained with back propagation algorithm is one of the most commonly used to train neural networks and is widely used in the time series forecasting (Kaastra and Boyd, 1996).

2. Data and Variables:

Following the previous studies (eg. Kavaklioglu, Ceylan , Ozturk and Canyurt ,2009; Saravanan, Nithya, Kannan, and Thangaraj, 2014; Kargar and Charsoghi, 2014, Kheraief and al. ,2016) variables such as GDP, population, and electricity price are considered to be the most important factors that affect electricity consumption. Therefore, the present study considers the following functional form of electricity demand function for Algeria:

$$E_t = f(Y_t, P_t)........................(1)$$

According to this specification the electricity demand is a function of the GDP per capita and the population. The variable electricity price is not used in our specification because it is generally fixed and greatly subsidized by the Algerian government. This study uses annual data of Algeria, covering the period from 1980 to 2016. These data are obtained from the world development indicators database (2017). Figures 3, 4 and 5 represent the evolution of electricity consumption, GDP and population.

As it can be observed from Figure 3, Algeria's electricity consumption has risen significantly in recent years. Between 2010 and 2016 electricity consumption rose from 33.84 billion kwh to 55.95 billion kwh, this means that the country has seen an increase of 65 percent in less than decade. This strong demand for electricity is driven particularly by the expansion of the economic activities and a rapid increase in the population growth (Bélaïd and Abderrahmani, 2013).

Table 1 shows the descriptive statistics for variables, and the correlations between them are reported in Table 2. As we can see from Table 3 there is a strong and significant correlation between the dependent variable (electricity consumption) and the independent variables (GDP per capita and population).

III- Results and discussion:

In this study, two ANN models are considered to estimate and forecast electricity consumption in Algeria. In the first ANN model electricity consumption is modeled as a function of two economic variables namely population and GDP per capita. In the second model it is modeled using time input only.
The study period spans the time period from 1980 to 2016.The number of observations used to train the network were set at 80 percent, while the remaining observations were used as test data. STATISTICA version 12 was deployed to train, test and validate the network. The data were split into training and testing sets.

To evaluate the accuracy of the MLP models, the Means Absolute Percentage Error (MAPE), and multiple fractions of variance (R^2) error were used:

$$MAPE = \left[\frac{1}{n} \sum_{i=0}^{n} \left| \frac{(P_i - A_i)}{A_i} \right| \right] \times 100, \quad R^2 = 1 - \frac{\sum_{i=1}^{n} (A_i - P_i)^2}{\sum_{i=1}^{n} (A_i)^2}$$

Where n is the size of the sample, A_i and p_i are the actual and the predicted values.

1. Modeling based on economic indicators:

Two independent variables namely GDP per capita and population were used as input values in the neural network, while the output was the electricity consumption. The characteristics of the selected model of artificial neural networks are given in Table 4. The ANN architecture selected consists of two inputs, seven hidden layers and an output layer. Hidden and output neuron activation functions of the selected network were the logistic and identity respectively. The training algorithm was the Broyden-Fletcher-Goldfarb-Shanno (BFGS). According to the results in table 3, the selected model has MAPE value (0.021 percent) below 0.05, and R^2 (0.97) value is very close to 1.

Comparison Graph (Figure 6) between actual data of the electricity consumption in Algeria and the predicted values of ANN model showed a similar pattern.

2. Modeling based on time:

Another models for forecasting electricity consumption are the time input models, in this type of models, all variables are considered to be a function of time, as expressed in equation 2.

$$\begin{bmatrix} GDP(t) \\ POP(t) \\ EC(t) \end{bmatrix} = f(t) .... (2)$$

The advantage of these models is that they capture both the static relationship among variables and the dynamic nature of the variables (Kavaklioglu and al. ,2009). For this model, years (time) is used as the input variable, population and GDP per capita are the predicted output variables. Several network architectures were tested to find the best architecture. The obtained results are given in table 5. A feed forward back propagation network with one input eight hidden and three output layers (MLP 1-8-3) was selected. Logistic and identity functions were used as activation function in the neurons of hidden layer and output neurons. The learning algorithm was the Broyden-Fletcher-Goldfarb-Shanno (BFGS), and the numbers of neurons in the hidden layers were varied from 2 to 10.

To evaluate the performance of the selected ANN model, actual data for electricity consumption, GDP per capita and population are graphically compared with the predicted values of the time input model in figure 4, figure 5 and figure 6. In addition, Means Absolute Percentage Error (MAPE) and multiple fraction of variance (R^2) error for each output variable are listed in table 6.

The visual analysis (see figure 7) of the actual and predicted electricity consumption indicates that the ANN time input model gives a best performance at capturing overall time behavior of electricity consumption. As in the electricity consumption estimation, the ANN time input model performs very well in capturing the time behavior of both GDP per capita and population (see figures 8 and 9).

From the results in table 6, the MAPE for electricity consumption is 3.3 %. It is evident that this is relatively high compared to the previous model, where the MAPE for electricity consumption was found to be 2.2 %. In addition, electricity consumption based on time input model has less R squared value (0.91) compared to the previous ANN model where electricity consumption was modeled as a function of economic indicators (R square 0.98).

Based on the comparison of both MAPE and R squared results, it can be said that modeling electricity consumption as a function of economic indicators (GDP per capita and population) using ANN is more appropriate than ANN time input model.

3. Future prediction:

Using the data based neural network model (MLP: 2,7,1) developed previously, the electricity consumption is forecasted until 2025 for Algeria. However, forecasted electricity consumption from 2017 to 2025 can be obtained only if the forecasted values of the input variables are estimated. The input variables namely GDP and population are forecasted from 2017 to 2022 by ANN method based on the previous data between 1980 and 2016. The forecasted results of independent variables are given in Table 7, and figures 10 and 11.

Finally, the previous ANN model that has been selected with actual data of 1980-2016 is now used to forecast future electricity consumption for the year 2017 to 2025 with estimated input variables. The results are given in Table 7, and figure 12.

The forecasted results show that electricity consumption will reach 76,61 billion Kwh in 2020, and 94,66 billion Kwh in 2025, which corresponds to an annual average growth rate of around 5.5 percent. Additionally, our selected neural network model predicts a 50 percent increase of the consumption of electricity in the recent 10 years.

For the forecasted population, the results indicated that Algeria’s population is predicted to be 47.3 Million by 2025, with an annual average growth of 1.9 percent, which is a large growth rate that requires more electric energy.

For the future prediction of GDP per capita, the results showed that between this variable follows an average growth rate of around 0.6 percent, however from the year 2020 to 2025 a slower growth rate of per capita GDP is projected (about 0.3 percent).

IV. Conclusion:

In this study, two Artificial Neural Network models are used to predict electricity consumption in Algeria, based on the historical data from 1980 to 2016. In the first model electricity consumption is modeled as a function of GDP per capita and population. The second is time input model, where both dependent variable and independent variables are considered to be a function of time. The performance of models has been evaluated by calculation both MAPE and R squared. The results obtained show that both models show good forecasting performance for the future. It is also concluded that the ANN model based on modeling electricity consumption as a function of economic indicators shows better performance than the ANN time input model. The limitation of the study is in the empirical part, where the analysis is performed using only ANN method for forecasting. In fact, several forecasting techniques can also be used and compared. Therefore, it is possible to use Least Square Support Vector Machine (LS-SVM) and Adaptive Neuro Fuzzy Inference System (ANFIS) along with ANN to forecast electricity consumption.

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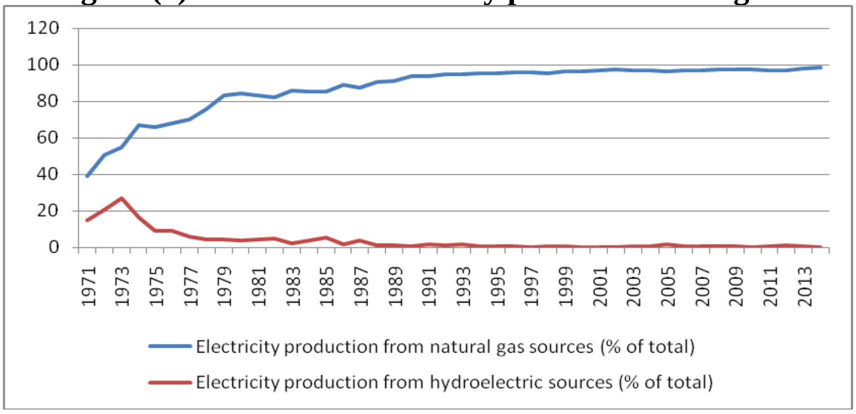
- Appendices:

Figure (1): Sources of electricity production in Algeria



Source: world Bank (2017)

Figure (2): General structure of neural networks

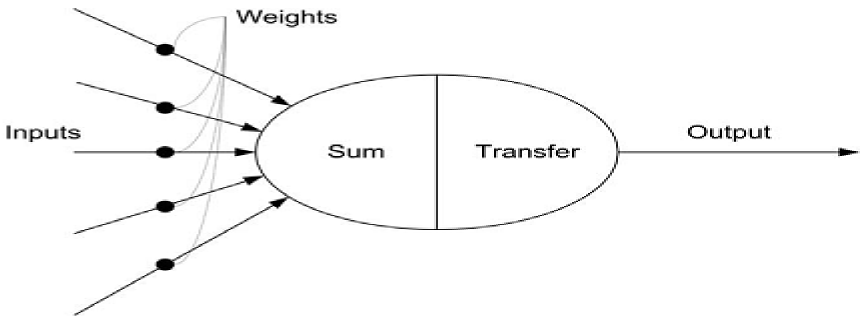
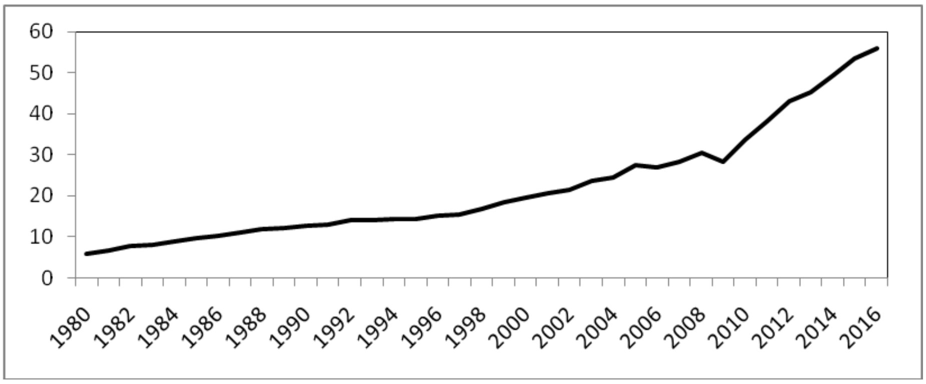


Table (1): The Algerian Renewable Energy target

source	1st phase 2015-2020 (MW)	2nd phase 2021-2030 (MW)	Total (MW)
Solar PV	3,000	10,575	13,575
Wind	1,010	4,000	5,010
CSP		2,000	2,000
Cogeneration	150	250	400
Biomass	360	640	1,000
Geothermal	5	10	15
Total	**4,525**	**17,475**	**22,000**

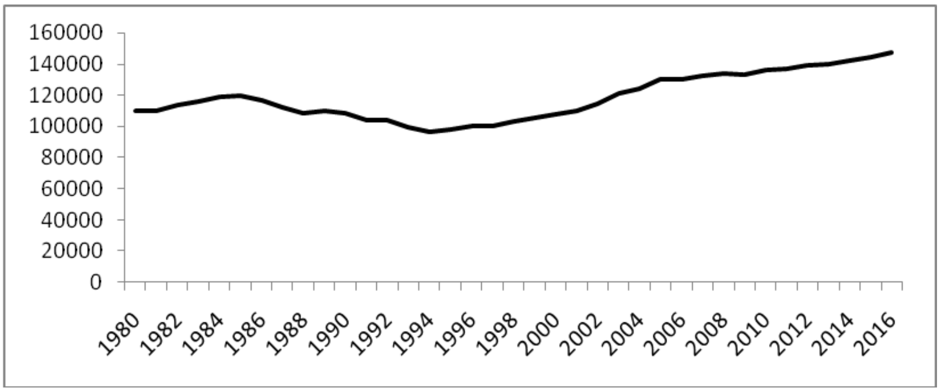
Source: International Energy Agency (IEA), Global Renewable Energy, (accessed: January 2019).

Figure (3): Electricity Consumption (Billion Kwh)



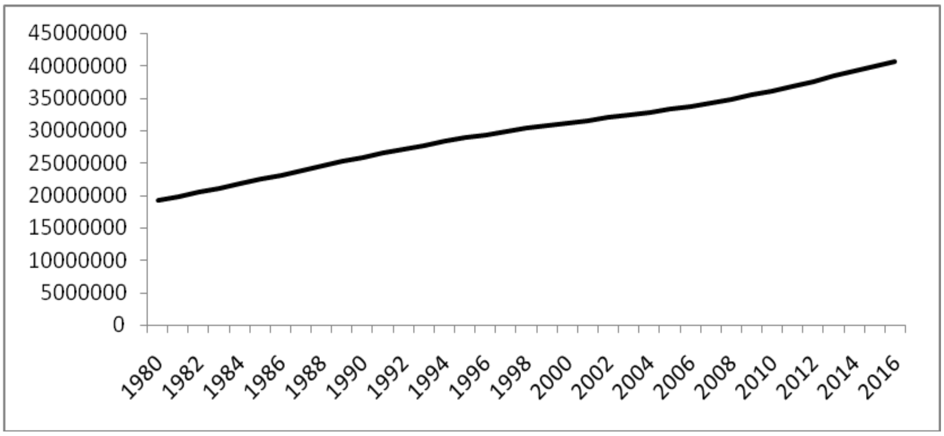
Source: U.S. Energy Information Administration

Figure (4): GDP per capita (at current DZD)



Source: world Bank (2018)

Figure (5): Algerian Population (Millions)



Source: world Bank (2018)

Table (2): Descriptive statistics of variables

Variable	Mean	Max.	Min.	Std. Dev.	Obs.
Electricity consumption (Billion kwh)	21.95	55.95	5.91	13.65	37
Population	29940122	40606052	19337715	6020060	37
GDP per capita (constant 2010 LCU)	118332.8	147551.0	96356.49	15001.49	37

Table (3): Correlations of the variables

	E	Y	P
E	1.000		
Y	0.844014 (0.0000)	1.000	
P	0.931744 (0.0000)	0.692758 (0.0000)	1.000

Note: p-Values are in the parentheses.

Table (4): The ANN analysis results

Output	**Electricity consumption**
Model	Feed-forward backpropagation
Input layer	2
Number of hidden layers	7
Number of output layer	1
Hidden Activation function	Logistic
Output Activation function	Identity
Training Algorithm	BFGS
MAPE	0,02187198
R^2	0.97

Figure (6): Actual and Predicted electricity consumption with population and GDP per capita as input variables

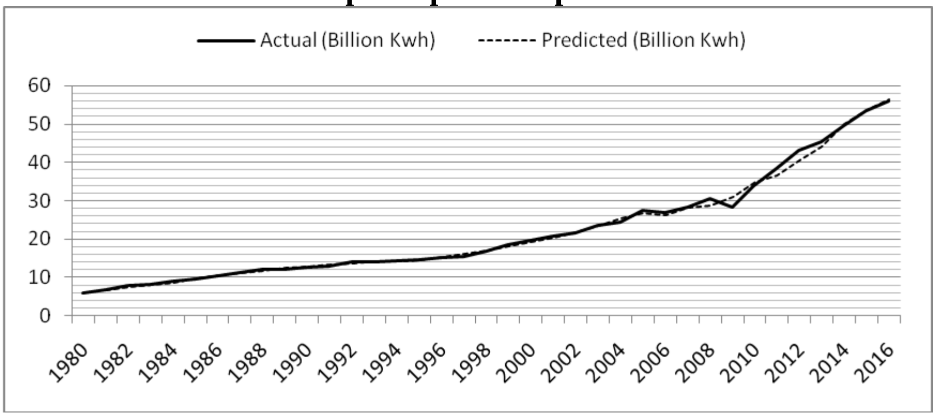


Table (5):The ANN analysis results

Output	**years**
Model	Feed-forward backpropagation
Input layer	1
Number of hidden layers	8
Number of output layer	3
Hidden Activation function	Logistic
Output Activation function	Identity
Training Algorithm	BFGS

Table (6): List of output variables and their MAPEs and R^2 s

Variable	**MAPE**	R^2
Population	0,00236129	0.999
GDP per capita	0,0145001	0.988
Electricity consumption	0,033404415	0.915

Figure (7): Actual and predicted electricity consumption with time only input

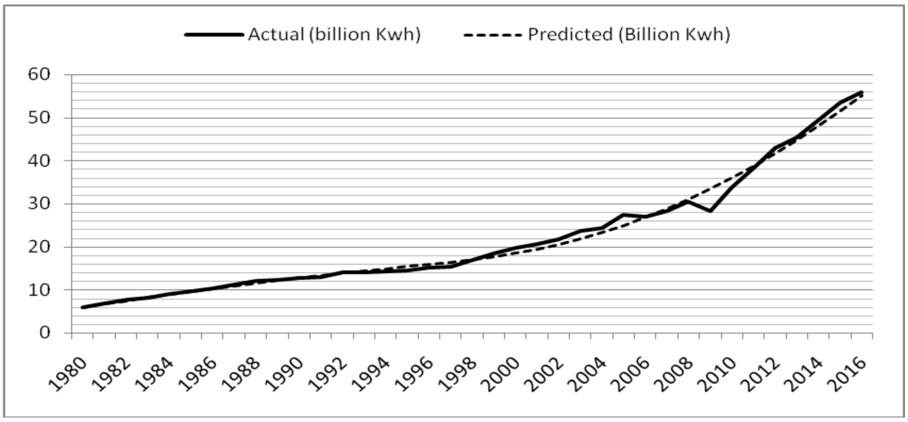


Figure (8): Actual and predicted GDP per capita with time only input

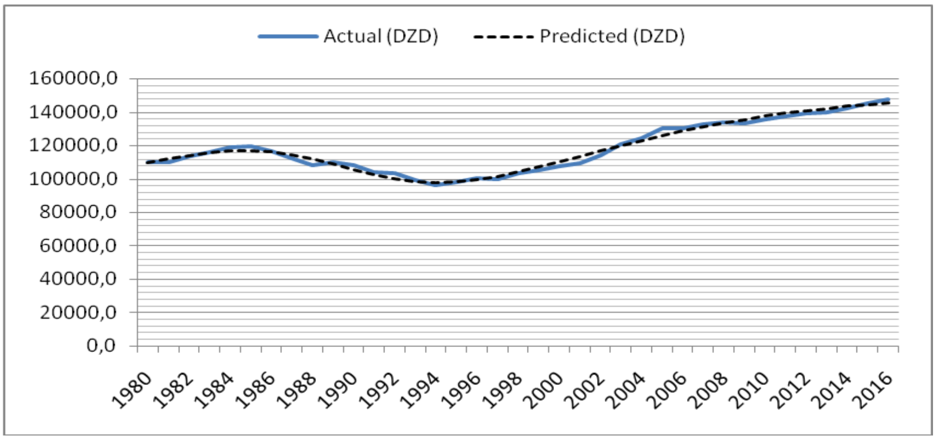


Figure (9): Actual and predicted population with time only input

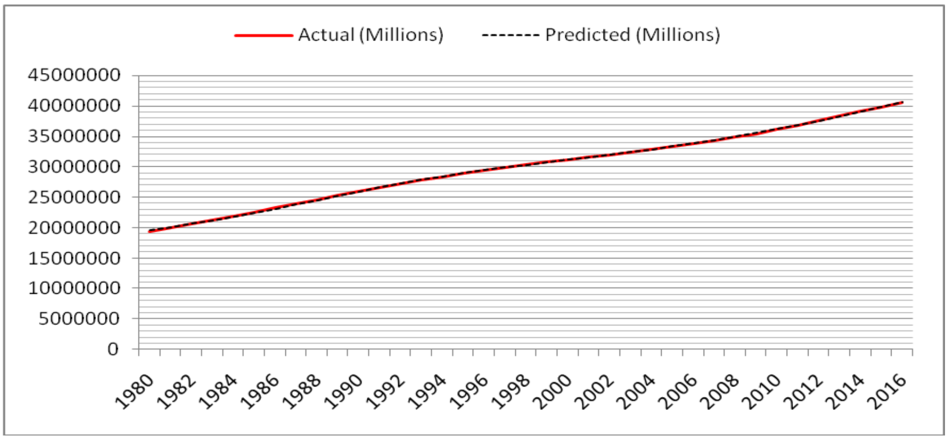


Table (7): Predicted values of electricity consumption and other inputs until 2025

year	Population (Millions)	GDP per capita (DZD)	Electricity consumption (Billion Kwh)
2017	40605646	145993,5	61,73297
2018	41317168	146961,6	66,84477
2019	42015668	147817,8	71,61732
2020	42717146	148569,5	76,06436
2021	43443221	149225,2	80,23007
2022	44222155	149794,0	84,15779
2023	45092044	150284,9	87,87313
2024	46106929	150706,7	91,37827
2025	47347289	151067,9	94,66536
Average growth rate	**1.9%**	**0.42%**	**5.5%**

Figure(10): Future population prediction

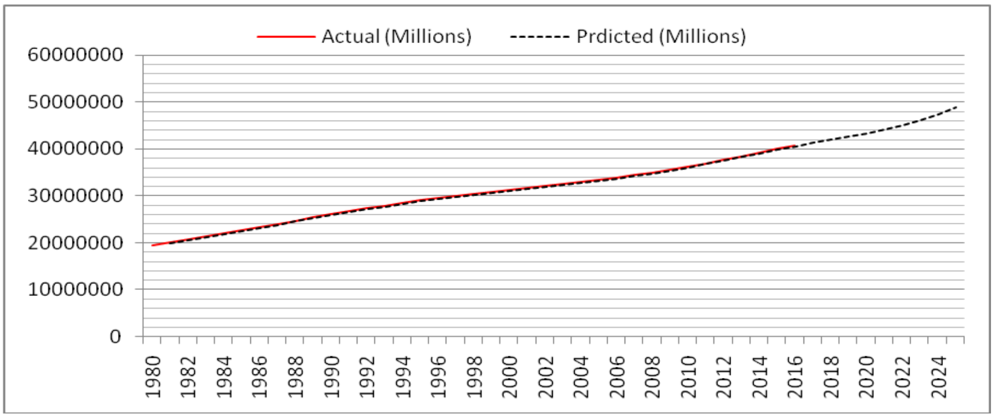


Figure (11): Future GDP per capita prediction

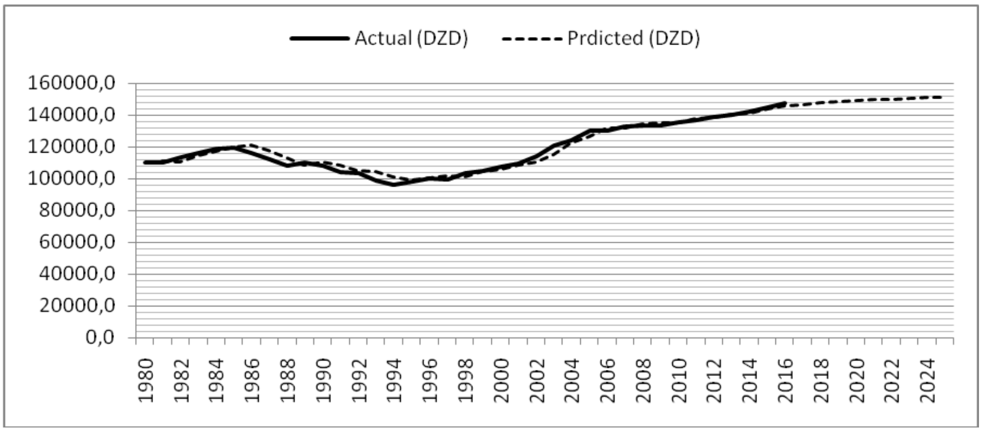
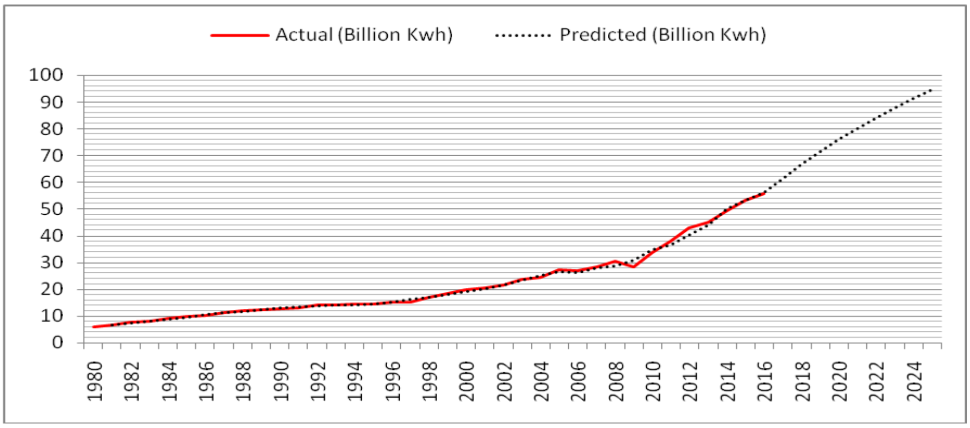


Figure (12): Future electricity consumption prediction



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