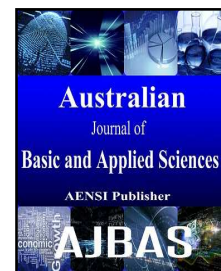




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# Predicting Energy Consumption And Analysis Of Energy Demand, Economic Growth Of India

<sup>1</sup>K. Latha and <sup>2</sup>S.Mohan

<sup>1</sup>Assistant Professor, Department of CSE, University College of Engineering Trichy, Tamilnadu, India.

<sup>2</sup>PG Scholar, Department of CSE, University College of Engineering Tiruchy, Tamilnadu, India.

### Address For Correspondence:

K. Latha, Assistant Professor, Department of Computer Science and Engineering, University College of Engineering Trichy, Tamilnadu, India.

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### ABSTRACT

The present study examines whether or not energy consumption fuels economic growth. The relationships examined by using the annual information covering the duration from 2000 to 2014. By employing the Granger causality test, the study through empirical observation found that it's economic growth that fuels more demand for lignite and electricity consumption and there's growth of any energy variables that causes economic growth. In contrast, the out of sample forecasts in variance decomposition of power unit suggests that there's a influence between energy consumption and economic growth. The eleven input variables used are quantity of CO<sub>2</sub> emission, Population, Per capita GDP, Per capita gross national income, Gross Domestic Saving, Industry, Consumer price index, Wholesale price index, Imports, Exports and Per capita power consumption. A new methodology supported Artificial Neural Networks (ANNs) victimed principal components is additionally used. Comparison done with multiple linear regression (based on input information and the principal components) and ANNs with original value as given Variable. The result shows that the use of ANNs with principal components (PC) is more effective.

### INTRODUCTION

The growth in energy used is essentially linked with the Growth in economy. Artificial Neural Network (ANNs) methods have a great deal of attention and were proposed as powerful computational tools to solve the load. Some amount of this major infrastructure is an important determinant of the success of a nation's effort in diversifying its production based, expanding trade and link together resources and markets into an integrated economy. However, the success of this sector is mainly based on the level of energy in the economy. In fact, transport sector is the largest user of energy in the economy (Reddy, A.K.N., Y.P. Anand and A. D'Sa, 2001; Samimi, R., 1995). The consumption of energy is likely to grow up further with economic growth development, population growth, industrialization, urbanization and modernization of agriculture (Ramanathan, R. and J.K. Parikh, 1999). Modeling and predicting electricity utilization play a important role in developed and developing countries for policy makers and supported Organization. The underestimation of the need would lead to potential outages that are devastating to life and economy but the overestimation may lead to unnecessary idle capacity which means wasted financial sources. Therefore, it may be better to new electricity demand with good accuracy in order to avoid costly mischievous (Adem Akpinar, *et al.*, 2011). Several methods have been developed to perform accurate long term load forecasting. These methods are normally classified into two types: conventional approaches and technique based on artificial intelligence. Load forecasting approaches on the basis of conventional methods forecast current value, where as in other method a variable on basis of the

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mathematical combination of the before values of that variables and current values of other variables (Bong, D.B.L., *et al.*, 2008). Chavez *et al.* (1999) used Auto Regressive Integrated Moving Average (ARIMA) time-series analysis models on basis of Box-Jenkins method to formulate the forecasting model for the prediction of energy production and requirement in Asturias, Northern Spain. Hor *et al.* implemented a multiple regression model for the prediction of load demand in England and Wales (Hor, C.L., *et al.*, 2005). The aim was to give an accurate model for a long-term prediction for the demand of each month and the evaluation of the model was done by using Mean Absolute Percentage Error (MAPE). Asber *et al.* dealt with the develop of a reliable and efficient Kernel regression model to forecast the Hydro load Québec distribution network (Asber, D., *et al.*, 2007). Li Yingying *et al.* made use of principal component regression in power load forecasting for medium and lengthy term (Li Yingying and Niu Dongxiao, 2010). From 1980s, Artificial Neural Network (ANNs) method received a great deal of listening and were proposed as great computational tools to solve the load forecasting problem (Henrique Steinherz Hippert, *et al.*, 2001). AI-Saba and EI-Amin described the application of ANNs to long-term load forecasting, they given the results were close to the actual data while using the ANNs (Tawfiq AI-Saba and Ibrahim EI-Amin, 1999). Forecasting evaluated the accuracy of each approach by calculating Mean Absolute error(MAE), MAPE and Root Mean Square Error (RMSE). Bohman Kermanshahi *et al.* used multilayer Preceptor and recurrent neural networks for finding prediction of high electric loads of Japan up to the year 2020, using input variables such as gross national product, GDP, population, number of households, number of air-conditioners, amount of  $CO_2$  emission, pollution, industrial production, oil price, amount of energy requirement, electricity price, average temperature and maximum electric power of the previous year (Kermanshahi B. and Hiroshi Iwamiya., 2002). In this paper, energy demand of India calculated by using RA, ANNs, joining RA with PC and joining ANNs with PC, which consider five input variables: Population, Per capita Gross Domestic Product, Import ,Export and per capita power consumption. This work says, the use of a new technique using ANNs based on principal components, therefore using statistical and artificial intelligence technique.

## 2. Factor of Economic Growth and Energy Consumption:

The input variables are found based on the relation between the energy demand and related parameters such as economic factors. After a careful investigation the following variables are selected as the input variables:

1. Amount of  $CO_2$  emission: The greenhouse gases emitted into the atmosphere over a particular area and period of time.
2. Population: It is believed that a high population growth rate will bring a high increase in total energy consumption. In India, with continuous development in the public revenue and living standards, energy consumption will increase with the standard growth of population and industrialization.
3. Per capita GDP: Economic growth measured by per capita GDP is an important factor in energy consumption. The effect of economic growth shown on energy demand.
4. Per capita gross national income: Gross national income combine the all value of goods and services produced within a country also with income received from other countries.
5. Gross Domestic Savings .
6. Industry
7. Consumer price index: It examines the weighted average of prices of a bucket of consumer goods and services, such as transport, food and medical care.
8. Whole sale price index
9. Imports: It consists movement of goods and services from non residents to residents
10. Exports: It consists of exchange of goods and services from residents to non-residents.

## 3. Reserves and Potential for Generation:

India's energy consist of both non-renewable (coal, lignite, petroleum and natural gas) and renewable energy sources (wind, solar, small hydro, biomass etc). Detail about the reserves of non-renewable sources of energy like coal, lignite, petroleum, natural gas and the ability for generation of renewable energy sources is a requested for assessing the country's ability for meeting its future energy needs.

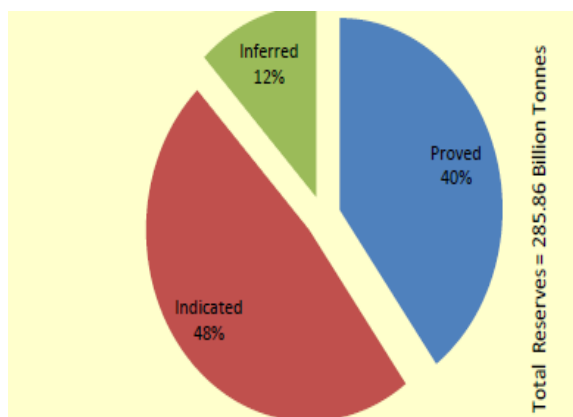
### Non-Renewable Resources:

#### 3.1 Coal and Lignite:

India has a high reserve of coal and lignite. As on 31.03.2011 the found reserves of coal was around 286 billion tones, an addition of 9 billion over the last year . Coal presence is mainly conformed to eastern and south central parts of the country. The states of Jharkhand, Orissa, Chhattisgarh, West Bengal, Andhra Pradesh, Maharashtra and Madhya Pradesh contain more than 99% of the total coal reserves in the country. The total estimated reserve of coal in India as on 31.03.2010 was around 277 billion tonnes. There is an increase of 3.1% in the calculated coal reserves during the year 2010-11 with Madhya Pradesh accounting for the maximum raise of 5 %.

### 3.2 Petroleum and Natural gas:

The calculated reserves of crude oil and natural gas in India as on 31.03.2011 stood at 757 million tones (MT) and 1241 billion cubic meters (BCM) respectively. Statistical analyzation of Crude oil indicates that the max reserves are in the Western Offshore (43%) continued upto Assam (22%), whereas the max reserves of Natural Gas are in the Eastern Offshore (35%) continued upto Western offshore (33%).

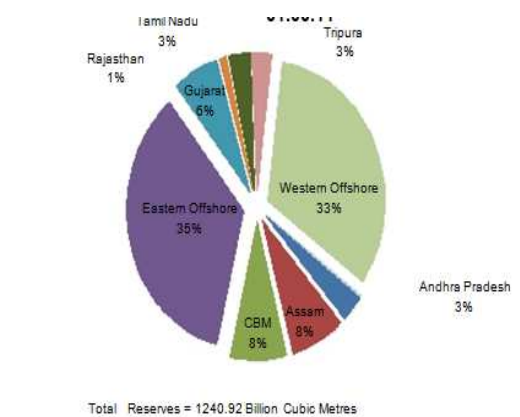


**Fig. 1:** Reserves of coal

There was a raise of calculated Crude Oil reserves by 33% in Andhra Pradesh continued upto Tamil Nadu (8%). But there was a reduction of 2% in the calculated reserve of crude oil for the country as a whole during 2010-11. In case of Natural as, the raise in the calculated reserves over the last year was 8%.

### 3.3 Renewable energy sources:

There is high ability for production of renewable energy from many sources- wind, solar, biomass, small hydro . The total ability for renewable power production in country as on 31.03.11 is estimated at 89760 (MW). This also contain calculated wind power potential of 49132 MW (55%), SHP (small-hydro power) potential of 15,385 MW (17%), Biomass power production of 17,538 MW(20%) and 5000 MW (6%) from bagasse cogeneration in sugar mills.



**Fig. 2:** Reserves of Natural Gas

The Statistical analyze calculate potential across States reveals that Gujarat has the greatest share of about 14% (12,489 MW), continued by Karnataka with 12% share (11,071 MW) and Maharashtra with 11% share (9596 MW), based on account of wind power potential.

### 4. Methodology:

PCA is a multivariate statistical method mostly used in analysis of data in diverge fields, because it is simple, nonparametric method. PCA is a variable reducing process. It includes mathematical procedure that transform number of (possibility) correlated variables into a small number of uncorrelated variables called principle components (PC). This mathematical method in PCA is called Eigen analysis: solve the Eigen values and Eigen vectors of a square symmetric matrix with sum of squares and cross products. The Eigen vectors combined with the largest Eigen values have the same direction as the first PC. The Eigen vectors combined

with the second largest Eigen values determines the direction of the second principle component. The sum of the Eigen values equals the trace of square matrix and the maximum number of Eigen vectors equals the number of rows (or columns) of this matrix. Linear regression is a form of RA in which observational data are modified by a least squares function, which is a linear combination of the model parameters. In simple linear regression, the function model represents a straight line or parabola. The data model, which represents simple linear regression given in eq 1.

$$Y = aX_1 + bX_2 + e \quad (1)$$

Where, Y is the dependent variable (Energy consumption),  $X_1$  and  $X_2$  are the independent variables (example: Population and Per capita GDP), „a“ and „b“ are the regression coefficients and „e“ is the error term. The error term denotes unexplained difference in the dependent variable and treated as a random variable. The factor Population and Per capita GDP are calculated to give a best fit of the data. The best fit is evaluated by using the least squares method. ANNs are able to give better performance in dealing with the nonlinear relationships among their input variables (Kazemi., A., 2009). It is proved that the multilayer perceptron with error back propagation is an appropriate model for long-term load forecasting (Kermanshahi B. and Hiroshi Iwamiya., 2002) also one hidden layer is enough to approximate any function (Sousa, S.I.V., *et al.*, 2007), if presenting enough hidden nodes. Therefore, multilayer perceptron has been chosen in this paper and the input variables are selected based on the correlation technique. The multilayer perceptron consists of (i) input layer (ii) output layer (iii) one or more hidden layers containing nodes which help to capture the nonlinearity in the data. A Neural Network can be trained to perform particular function by adjusting the values of weights between elements so that a particular input leads to a specified target output. Therefore, the network is adopted, based on a comparison of the output and the target. Using supervised learning, these networks can learn the mapping between one data spaces to others

**Table 1:** Variance of original InputVariable

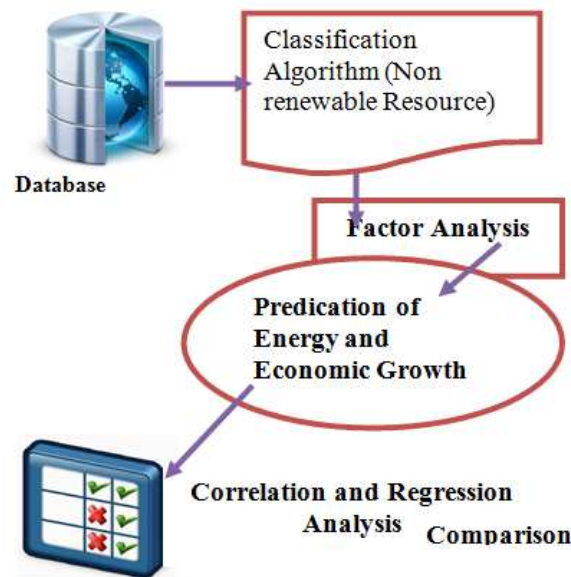
Component	1	2	3	4	5	6	7	8	9	10	11
EigenValue	10.07	0.56	0.34	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00
% Variance	91.56	5.04	3.10	0.14	0.09	0.02	0.01	0.00	0.00	0.00	0.00
Cumulative %	91.56	96.6	99.7	99.85	99.94	99.97	99.99	99.99	99.9	100.0	100.0

Table.1 shows the total variance of the original variables. The seven largest Eigen values in eleven characteristics roots exist in variable correlation matrix, respectively 10.072, 0.555, 0.341, 0.016, 0.010, 0.003, 0.002 and their cumulative contribution to the total explained variance is 99.99%. The first seven principal components provide the most information of original data and extracted.

Data normalization within a proper range is essential (i) to prevent larger numbers from overriding smaller ones, and (ii) to protect premature saturation of hidden nodes, which impedes the learning process (Sackdara, 2010). In most cases, the ANNs are obtained using two distinct data sets: training and validation. The training data set is used to determine the network topology and combined weights by solving a non-linear optimization problem with the objective function being dictated by the mean squared error (MSE).

The input variables are selected based on the correlation coefficients between the electricity consumption and corresponding economic factors. These correlation coefficients provide the measure of the relation between the two variables. High correlation coefficient was found between these input variables and predicted output variables. Therefore these variables were used to provide the future electricity consumption in India. The statistical package for social studies (SPSS) are used for applying RA and ANNs and XL Pro are used for applying PCA on a desktop PC with system configuration Intel Core2duo CPU, 2.67 GHZ with 1 GB RAM. RA and ANNs are used to predict the electricity consumption. These models are based on the original data (RA and ANNs) and on the PC (PCR and PC-ANNs).

#### 4.1 Architectural Diagram:



**Fig. 3:** System Architectural diagram

Fig 3 shows Architecture of system, which explains that data extracted from database that contain all energy resources, two type of energy resources namely 1. Renewable Energy Resources 2. Non Renewable Energy Resources. These Energy Resources are classified into two and Factor which affect the energy resources and economic growth is analyzed. After Analyzing factor just undergoes predicting energy consumption and analysis of economic growth with energy demand of India.

#### 4.2 Performance Analysis:

The input factors are taken based on the correlation coefficients between the energy consumption and corresponding economic factors. These correlation coefficients provide the measure of the relation between the two variables. High correlation coefficient was found between these input variables and predicted output variables. Therefore The statistical package for social studies (SPSS) are used for applying RA and ANNs and XLPro are used for applying PCA on a desktop PC with system configuration Intel Core2duo CPU, 2.67 GHZ with 1 GB RAM. RA and ANNs are used to predict the electricity consumption. These models are based on the original data (RA and ANNs) and on the PC (PCR and PC-ANNs).

The prediction of electricity consumption based on the eleven input variables. To apply the ANN model several network structure were tested to find most opt topology. The architecture contain of a three layer network with eleven neurons in the input and eight neurons in the hidden layer and one neuron in the output layer. Sigmoid and hyperbolic function were used as activation function in the neurons of hidden layer and output neurons. To evaluate the performance of the ANNs with back propagation algorithm (original variables as inputs) results are compared with the RA. Considering seven PC inputs, and applied for the given models.

The statistical parameters are the Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), Mean Bias Error (MBE) is given by the Eq.(2 – 4).

$$RMSE = \sqrt{\sum_{i=0}^n (A_i - P_i)} \quad (2)$$

$$MAPE = \left( \frac{1}{n} \sum_{i=0}^n \left| \frac{P_i - A_i}{A_i} \right| \right) \times 100 \quad (3)$$

$$MABE = \frac{1}{n} \sum_{i=0}^n (P_i - A_i) \quad (4)$$

Where,  $P_i, A_i$  are the predicted values and actual values, and “n” is the total number of predictions. MAPE and RMSE measure the errors of residual, which gives all idea of the difference between the predicted values and actual values. MBE denotes if the predicted data are over/under estimated. The values of the statistical parameter results using RA and ANNs (original and PC data) for both training and validation stage

**Table 2:** Per Capita Energy Consumption and Energy intensity in India .

1975-76	840.53	617248	596428	1361.74
1980-81	1012.58	688320	695361	1471.09
2007-08	4508.26	1147677	3402716	3928.16
2010-11(p)	5693.54	1182105	4877842	4816.44
Growth rate(%)	4.23	0.56	9.27	3.65
CAGR(%)	5.38	1.88	5.63	3.44

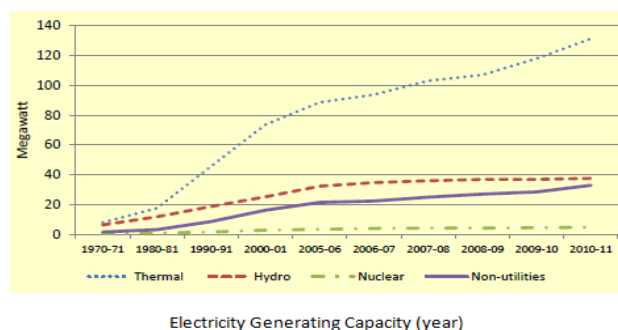
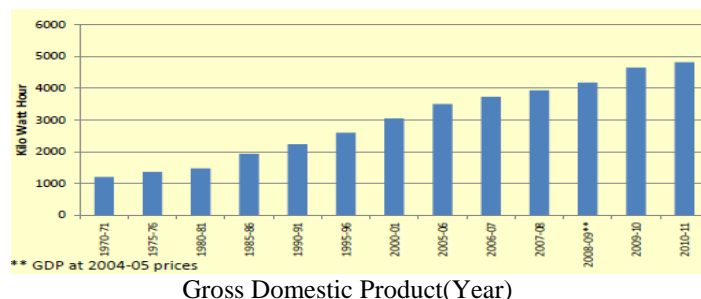
Table 2 shows Sample data set of Per capita Energy Consumption and Energy intensity in India. Data which contain energy consumption, population ,GDP of a country and per capita Energy consumption of India.

The actual electricity consumption in the year 2000 was 407.477BkWh, and in the year 2009 was 689.537 BkWh. The electricity consumption calculated, using RA with original variables as input.The output were 418.496 BkWh and 692.052 BkWh for the year 2000 and 2009. The MAPE is 0.969, RMSE is 7.189 and MBE is 6.218. The electricity consumption calculated using ANN with original variables as input. The results were 404.370 BkWh and 692.360 BkWh for the same year. The MAPE is 0.507, RMSE is 3.160 and MBE is 2.77. The electricity consumption calculated using RA with PC as input.

**Table 3:** Abbreviations used

S.No	Abbreviation	Expansion
1	ANN	Artificial Neural Network
2	GDP	Gross Domestic Product
3	PC	Principal Components
4	RA	Regression Analysis
5	MAPE	MeanAbsolute Percentage Error
6	RMSE	Root Mean Square Error
7	MBE	Mean Bias Error
8	MAE	Mean Absolute Error

From the fig 4, fig 5 the Per-capita Energy Consumption (PEC) during a year is calculated as the ratio of the estimate of total energy consumption during the year to the estimated middle-year population of that year. Energy Intensity is defined as the amount of energy consumed for generating one unit of Gross Domestic Product (At steady prices). PEC and Energy intensity are the most used policy indicators, both at national and international levels.

**Fig. 4:** ElectricityGeneratingCapacity in India**Fig. 5:** Per capita Energy Consumption

In the absence of data on need of non-conventional energy from various sources, especially in rural areas in the developing nation, including India, these two factor are generally computed on the basis of need of conventional energy. The annual increase in PEC from 2009-10 to 2010-11 was 3.65%. The Energy Intensity (at 1999-2000 prices) increased from 0.128 KWh in 1970-1971 to 0.165 KWh in 1985-1986, but it has again come

down to 0.117 KWh(at 2004-05 prices) in 2010-11 It is seen that the lot of source of energy consumed was Electricity accounting for about 51% of the total need during 2010-2011. Coal and Lignite were second (25%), where as Crude Petroleum (20%) was third. The total need of energy from conventional sources raised from 40,354 peta joules during 2009-10 to 42,664 peta joules during 2010-11, showing an raise of 5.73%.

### 5. Conclusion and Future Work:

Forecasting method are quite important for effective implementation of energy policies. In this paper, the net energy consumption of India is modeled as a function of economic factors: Amount of  $CO_2$  emission, Population, Per capita GDP, Gross national income, Gross Domestic savings, industry, Consumer price index, Wholesale price index, Imports, Exports and per capita power consumption. These economic factors (input variables) were selected through calculation of correlation coefficient. This way of selecting these factors for India is one of contribution of our paper. Two different approaches were used: one is original data, as input variables and the other is PC data as inputs. The results showed that the use of ANNs which led to more correct results than linear models (MLR and PCR).The energy consumption is complex with multiple influencing factors, so regular prediction models do not well for its prediction due to the account of nonlinearities. Thus by using this method, predicting the future requirement of non renewable energy and this energy demand is analyzed with economic growth of India . By this analysis we suggest non renewable energy demand will affect economic growth directly, which led to decrease of economic growth of India .Thus we shift to renewable energy resources to have good economic condition and good environmental condition.

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