Energy Models for Renewable Energy Utilization and To Replace fossil fuels

Iniyan S
Department of Mechanical Engineering, Anna University, Chennai-25, India
E-mail: iniyan777@hotmail.com
Jebaraj S
Department of Mechanical Engineering, Bharath Institute of Science and Technology, Chennai, India.
E-mail: jebakirjeba@rediffmail.com
Suganthi L.
Department of Management Studies, Anna University, Chennai-25 , India
Email:suganthi2764@yahoo.com
Anand A Samuel
Vellore Institute of Technology, Deemed University, Vellore, India
Email: anand_samuel@hotmail.com

Abstract

Models have become standard tools in energy planning. In recent years, considerable efforts have been made to formulate and implement energy planning strategies in various countries. The objective of this study is to predict the electricity consumption in India for the year 2020 by using Artificial Neural Network (ANN) and meeting the electricity requirement using an Optimal Energy Allocation Model (OEAM). The forecast of total electricity consumption in India for the year 2010, 2020 and 2030 is 603382, 944523.9 and 1395754 GWh respectively. An Optimal Energy Allocation Model (OEAM) was also developed for the replacement of fossil fuels with renewable energies to the maximum extent for the year 2020. The model was formulated with the objective of minimizing the cost of power generation subject to the constraints of demand, potential, efficiency, emission and carbon tax. The fuzzy constraints are used in the model. The possible energy options have been considered in the model to meet the electricity demand in India. The end result of the model is, renewable energy sources would replace the fossil fuels to an extent of 32% in the year 2020. These models are applicable for any country with necessary changes in the model input.

Key words: Energy Models, Renewable energy, and Replacement of Fossil fuels.

1.INTRODUCTION

The various types of forecasting models and optimization energy allocation models are reviewed and presented here briefly. A two layered feed forward artificial neural network forecasting model has been developed to relate the electric energy consumption in the Eastern Province of Saudi Arabia to the weather data, global radiation and population. (Javeed Nizami and Ahmed G. Al-Garni, 1995)[1]. A neural network based energy consumption model was developed for the Canadian residential sector (Merih Aydinalp et al, 2002) [2].

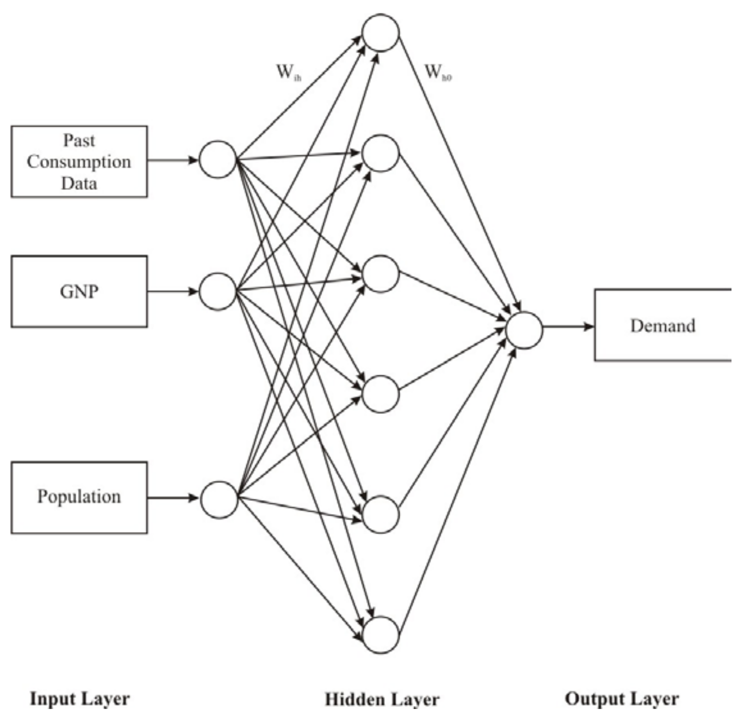
Che-Chiang Hsu and Chia-Yon Chen (2003) have collected empirical data to formulate an artificial neural network model to predict the regional peak load of Taiwan [3]. The Mathematical Programming Energy-Economy-Environment (MPEEE) model was developed by Suganthi and Jagadeesan (1992). [4]. A linear optimization model and a multi-attribute value model were introduced by Mustafa Tiris et al (1994), to estimate the long-term energy, economy and environment for Turkey [5]. The Optimal Renewable Energy Model (OREM) was formulated to find the optimum level of utilization of renewable energy sources in India for the year 2020 – '21 (Iniyan and Jagadeesan 1998) [6]. A fuzzy multi-objective linear programming approach to solve the energy resource allocation was evolved by Chedid et al (1999) [7]. In the present models, energy prediction was done by ANN model and energy allocation by OEAM model for India in the year 2020.

2. METHODOLOGY

The methodologies of Artificial Neural Network (ANN) forecasting model and Optimal Energy Allocation Model (OEAM) are explained below:

2.1 Artificial Neural Network (ANN) Forecasting Model

Picture 1 illustrates the pictorial representation of the Artificial Neural Network (ANN) model. The present analysis utilizes Artificial Neural Network

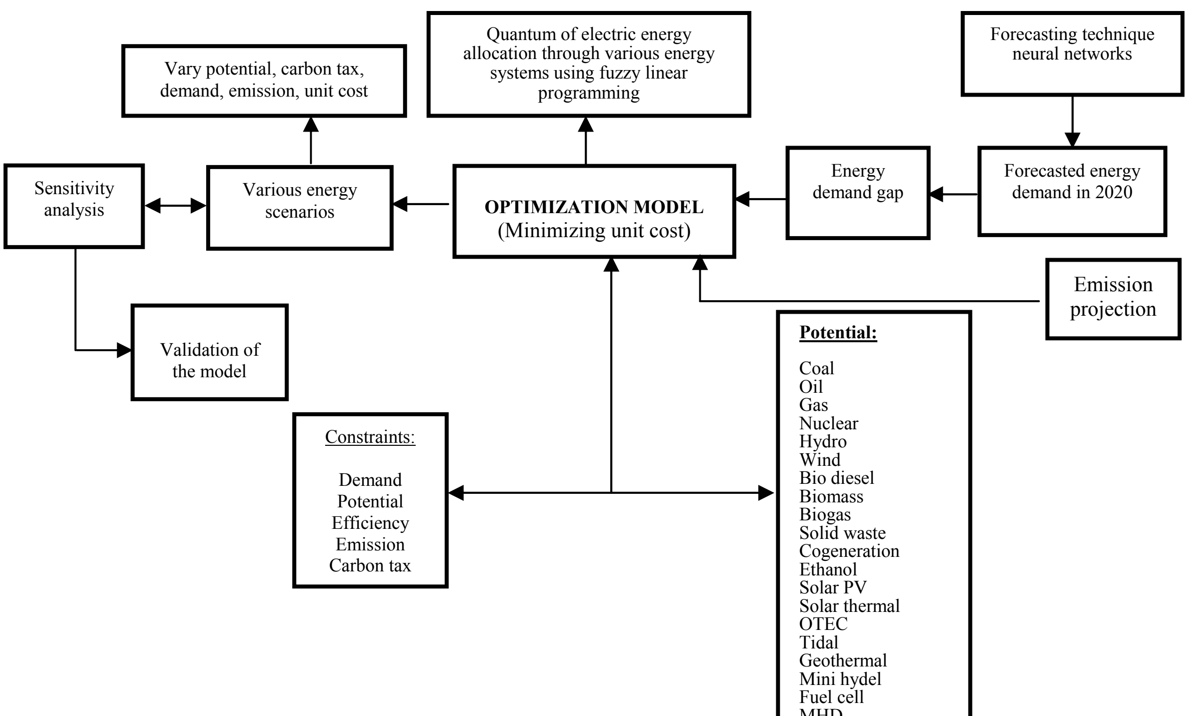


Picture 1. Pictorial representation of the multivariate ANN model.

(ANN) model for the electricity demand forecasting. In general ANN models are computational paradigms that implement simplified models of their biological counter part and biological neural structures. Accordingly, ANN's are characterized by local processing in artificial neuron i.e. parallel processing, which is implemented by the rich connection pattern between processing elements. The basic building block of the ANN is the artificial neuron. The neurons are grouped together in parallel to form layers. The layers are interconnected through the weighting factors. Signals can flow from the input layer through to the output layer in two ways, which is unidirectional or bi-directional.

2.2. Optimal Energy Allocation Model (OEAM)

The schematic representation of the Optimal Energy Allocation Model (OEAM) is given in Picture 2. The possible energy options have been considered in the model to meet the electricity demand in India. The model optimizes and selects the appropriate energy options for power generation using factors such as cost, potential, demand, efficiency, emission and carbon tax. The objective of the model is minimizing the cost of power generation. The other factors are used as constraints in the model. The mathematical representation of the Optimal Energy Allocation Model (OEAM) is given in the following equations:



Picture 2 Schematic representation of the Optimal Energy Allocation Model (OEAM)

<u>Mathematical representation of the model</u>

(1) $$\text{Minimize} \quad Z = \sum_{i=1}^{l} C_{ij} X_{ij}$$

Subject to constraints

(2) Potential $$\sum_{k=i}^{19} \left[\sum_{i=1}^{m} (X_{ij}) \le P_k \right]$$

(3) $$\text{Demand} \sum_{i=1}^{l} X_{ij} \ge D_j$$

(4) $$\text{Efficiency} \sum_{i=1}^{l} \eta_{ij} X_{ij} \ge D_j$$

(5) Emission $$\left[E_n \sum_{k=1}^{19} \left[\sum_{i=1}^{m} (X_{ik}) \le T_n \right] \right]$$

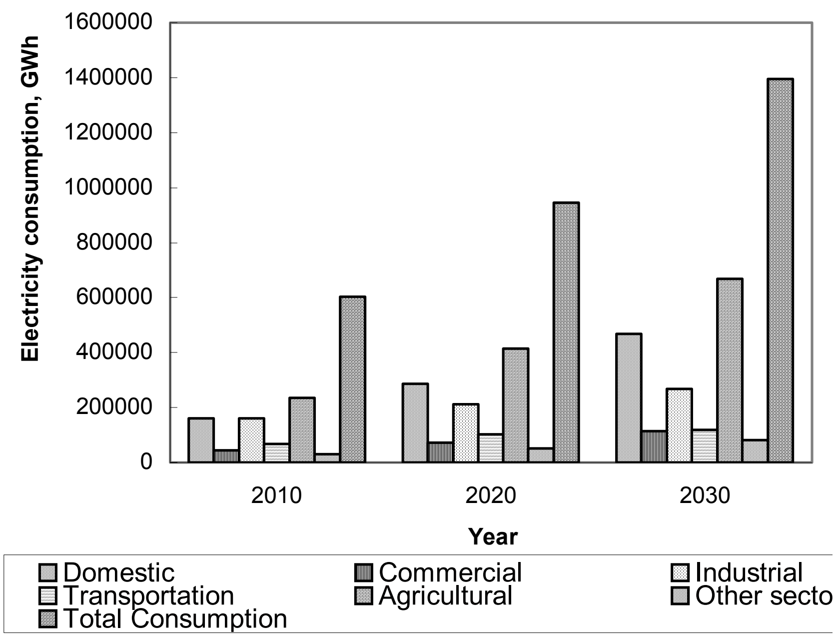
(6) Carbon Tax $$\left[E_n \sum_{k=1}^{19} \left[\sum_{i=1}^{m} (X_{ik} r) \le T_n R \right] \right]$$

where

C	=	Unit cost of the energy system
η	=	Efficiency of the energy system
l	=	Number of energy systems for power generation = 20
m	=	Number of system in respective resources = 20
D	=	Energy demand (GWh)
k	=	Resources
P	=	Potential of sources (GWh)
E_n	=	Emission constant (g/GWh)
T_n	=	Target emission level (g/year)
r	=	Carbon tax (Rs/ton)
R	=	Projected carbon tax in 2020 (Rs/ton)
X	=	Quantum of energy (GWh)
i	=	Various energy systems
j	=	Power generation.

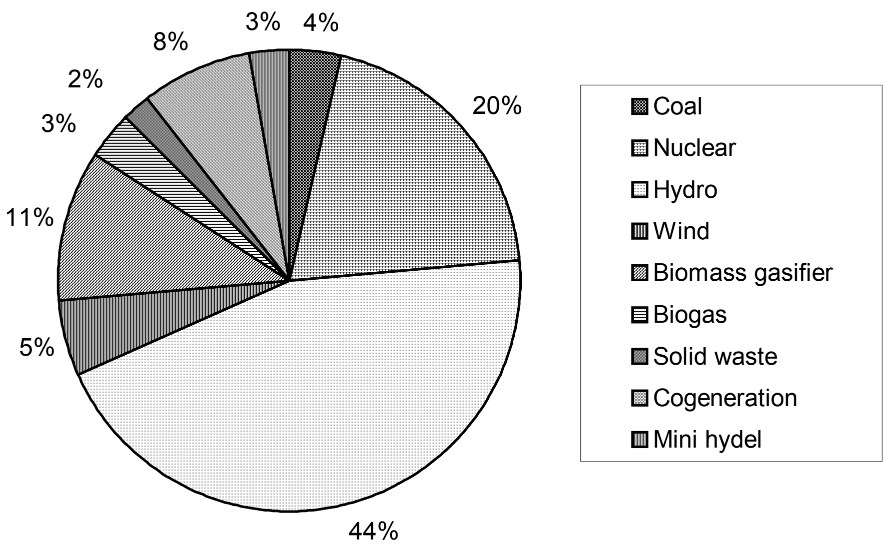
3. RESULTS AND DISCUSSION

The forecast of electricity consumption in India in different sectors such as domestic sector, commercial sector, industrial sector, transportation sector, agricultural sector and other sectors for the year 2010, 2020 and 2030 is presented in Picture 3. It is found that the consumption of total electricity is increasing every year in a very rapid manner due to the development in technology and improvement in the standard of living and lifestyle of the people. The forecast of electricity consumption in India for the year 2010, 2020 and 2030 is 160,524.2, 287,089.3 and 467,619.5 GWh respectively in the domestic sector, 43,166.68, 72,740.67 and 114,210.8 GWh respectively in the commercial sector, 160,392, 210,974.5 and 268,385.9 GWh respectively in the industrial sector, 68,461.86, 101,553.2 and 118,126.7 GWh respectively in the transportation sector, 235,117, 414,754.1 and 669,158.1 GWh respectively in the agricultural sector and 30,907.11,51,946.52and 81,304 GWh respectively in the other sectors. Also, the forecast of total electricity consumption (including all sectors) in India for the year 2010, 2020 and 2030 is 603,382, 993,385 and 1395,754 GWh respectively.



Picture 3 Forecast of electricity consumption in India

The Optimal Energy Allocation (OEAM) has been developed for the year 2020 to bridge the energy gap between predicted demand and present supply. The model was developed based on minimizing cost as the objective function and potential, demand, efficiency, emission and carbon tax as the constraints. The OEAM model pictures the optimum allocation for energy sources in India for the year 2020 (Picture 4). It is observed that the hydro based power generation amounts to 191100 GWh, which is nearly 44% of the total energy demand. Subsequently, the nuclear power plants supplies around 85,400 GWh (20%). But, coal based power plants accounts for 15,800 GWh, which is only 4% of the total demand. Also, the power generation from diesel and gas based plants is negligible. Hence, the conventional energy sources meet nearly 68% of the total demand. The remaining 32% of demand is met by the renewable energy sources namely, wind, biomass gasifier, biogas plants, solid waste, cogeneration and mini hydel based power plants. Among the renewable energy based power generation, the biomass gasifier based power generation contributes to nearly11% of the total demand, which generates 45,520 GWh of electricity and 5% (22,400 GWh) of the total energy demand is met by wind based power generation.



Picture 4 optimal electric energy distribution patterns for the year 2020 in India

The contribution of biogas plants, solid waste, cogeneration and mini-hydel plants for the power generation is 3% (14,112 GWh), 2% (8,400 GWh), 8% (33,600 GWh) and 3% (11,970 GWh), respectively. The power generation from the biodiesel-based plants, ethanol, solar, OTEC, tidal, geothermal, fuel cell and MHD have not been selected in the baseline model. However, the model selects the above systems at the time of different scenarios.

5. CONCLUSION

In the present study, the energy demand has been predicted for the year 2020 using the Artificial Neural Network (ANN) model. An Optimal Energy Allocation Model (OEAM) has also been developed to meet the energy demand in 2020. The forecast of total electricity consumption (including all sectors) in India for the year 2020 would be 993,385 GWh. The OEAM model replaces fossil fuels to an extent of 32% of total electricity consumption by renewable energy sources. It is concluded that the ANN forecasting model and the OEAM models would be very helpful to policy makers for future energy planning in India.

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