CHAPTER 3

A LITERATURE REVIEW OF ENERGY MODELS

A detailed literature survey has been conducted for various energy models such as energy planning models, energy supply-demand models, forecasting models, renewable energy models, optimization models, energy models based on Artificial Neural Network (ANN), energy models based on fuzzy logic and emission reduction models. Models have become standard tools in energy planning. In recent years, considerable efforts have been made to formulate and implement energy planning strategies in developing countries. Appropriate methodologies for conducting energy surveys to estimate and project sectoral useful energy requirement are evolved. This chapter gives a brief overview of the various types of energy modelling.

3.1 ENERGY PLANNING MODELS

Researchers and scientists had tried developing integrated energy models linking both commercial and renewable energy sources. A brief review of these integrated energy system models has been presented here.

A simple model was proposed by Peter (1977), which enables one to find conditions for the economic viability of solar thermal or solar photovoltaic energy conversion. Marchetti (1977) had developed a synthetic model of primary energy substitution. The societal efficiency, literacy and mineral resources were used as variables in the model. In the same year, Martin O. Stern (1977) had presented a quasi-equilibrium policy-impact

Steven Fawkes (1987) had presented a model of the energy management process developed using a soft systems methodology. The model divides the energy management into four levels, namely, good housekeeping, retrofit projects, plant replacement projects and new process design. From the model, a number of checklists for energy managers had been developed and presented. The use of different Energy-Signature (ES) models for energy consumption predictions and building parameter estimations were reviewed by Stig Hammarsten (1987). George et al (1987) had presented the integrated energy-planning model using a multiobjective programming technique linked with the traditional Leontief input-output model. Labour, GDP (Gross Domestic Product), resource availability, inter industry interactions and sectoral capacity bounds were the variables considered in the model. Sultan Hafeez Rahman (1988) had formulated an econometric energy-economy simulation model for energy policy studies for a wide range of developing countries. The variables used in the model were GDP and investment. Also, the model had been used for long-term energy demand forecasting for India. Several important issues in the areas of energy policy and planning for the future relating to developing countries were narrated by Natarajan (1990). The correlations between energy use and national income, and standard of life and quality of life were examined. Also, he had presented the special role of electricity in end-use and the role of renewable energy sources in energy supply for a developing country like India. Capros et al (1990) had presented the main theoretical and empirical
issues encountered in the construction of a short/medium-term energy-economy linked system of models, namely the Hermes-Midas system. The use and limitations of economic models in the corporate environment were described by Arnold and Anthony (1990). They had reviewed the alternative model types and their applications for business environment analysis, investment alternatives and strategic decisions. A study on model credibility was conducted by Yoichi Kaya (1990) in Japan. More than 10 economy wide models were selected and GNP results were compared. David B. Reister (1990) had discussed the various engineering-economic approaches for developing energy demand models.

The evolution of input-output techniques and the associated linear and non-linear programming models had been introduced. The basic structures and mechanisms of multi-sectoral input-output planning models were then discussed including the objective function and various types of constraints. The standard PILOT macroeconomic model and a multi-sectoral model of China were presented (Xia Shi and Yingzhong Lu 1990). John P. Weyant (1990) discussed the overview of policy modelling, in which he explained how data analysis and modelling could be used in planning in the volatile environment in which the industry currently operates. The integrated modelling theory was discussed by Walter C. Labys and John P. Weyant (1990). NAPAP Integrated Model Set was illustrated by Gale Boyd et al (1990), which constitute a collection of engineering, emissions, forecasting and energy-market models. Huq’s model of integrated rural energy systems in revised form for a village in Bangladesh was derived and the model forms the basis for the development of a computer model based on the system dynamics methodology of Forrester for policy planning (Alam et al 1990). Paul J. Werbos (1990) had compared the econometric modelling with other forms of modelling used in energy modelling and engineering. He had also developed a model PURHAPS for the Energy Information Administration
The theory of the process models with respect to the industry was discussed by Walter C. Labys and Hiroshi Asano (1990).

The use of dynamic programming in system expansion planning models was discussed by Leslie A. Poch and Jenkins (1990). A brief overview of the dynamic programming methodology was presented along with an example of how dynamic programming was applied in a model developed for electric system expansion planning. The introduction of multiobjective programming methods into a large-scale energy systems planning model was discussed by Psarras et al (1990). The author(s) reviewed several multiobjective techniques, ranging from simple methods to complex interactive algorithms providing best compromise solutions. An algorithm, which implements a decentralized hierarchical decision process with multiple objectives, had been reviewed and applied. Walter C. Labys et al (1990) had reviewed the various types of special programming models such as, elementary spatial programming, quadratic programming, mixed integer programming and linear complimentary programming models. Mental and computer models were at the foundation of intelligent human decision, and they were intimately related. The relation between these models was outlined which identifies major approaches to model development and explores future evolution of model interactions (Oliver S. Yu 1990). An analysis of the pay-off matrix technique, an approach to the solution of decision problems had been presented (Lev S. Belyaev 1990). Special Wald, Laplace and Subjective probability estimations had been applied in the technique. Robert Entriken and Gerd Infanger (1990) discussed the difficulties introduced by the stochastic parameters and review different approaches to handle them.

The author(s) (Thomas R. Bowe et al 1990) had introduced the use of Markov models for engineering-economic planning. Markov models capture the uncertainty and dynamics in the engineering-economic decision
environment. The author(s) describes how, when and why to use Markov models. The steps of model formulation, parameter estimation and solution had been described. The optimization decisions by stochastic programming were also presented. Decision analysis in engineering-economic modelling had been discussed by Douglas M. Loagn (1990) with uncertain outcomes and difficult trade-offs, to evaluate the alternatives available to a decision maker and to rank them in light of his information and preferences. Also, a multicriteria evaluation method had been used to evaluate the alternatives for new energy-system development in Taiwan (Gwo-Hshiung Tzeng et al 1992). The energy systems selected both conventional and renewable energy systems such as solar, wind and biomass as future energy options. Energy modelling of a food industry, for which a cogeneration system was proposed in order to obtain electrical energy together with steam and hot water for process heat had been presented by Calderan et al (1992).

Bharati Joshi et al (1992) had developed a simple linear decentralized energy planning model for a typical village in India for both the domestic and irrigation sectors to minimize the cost function for an energy-supply system consisting of a mix of energy sources and conversion devices. A personal computer based linear programming model of an Integrated Energy System for Industrial Estates (IESIE) was developed as a prefeasibility tool (Brahmanand Mohanty and Haribandhu Panda 1993). Mackay and Probert (1993) had discussed the future problems of the oil industry. Nilsson and Soderstrom (1993) had framed a production-planning model with optimal electricity demand with respect to industrial applications. A model that simulates the performance and economics of a combined wind/hydro/diesel plant with pumped storage was developed by Ashok Sinha (1993). Bala Malik et al (1994) had described an integrated energy system planning approach for Wardha district in Maharashtra, a state in India for the year 2000 AD. Also, an optimal mix of new/conventional energy technologies
using a computer based mixed integer linear programming model was presented. Blake E. Johnson (1994) had reviewed the assumptions and important insights of the investment theories relating to energy technology. The theories addressed include the capital asset pricing model, the arbitrage pricing theory and the theory of irreversible investment. Zaheer-Uddin and Zheng (1994) had developed a model, which had been used to simulate various Energy Management Control (EMC) functions. Andy S. Kydes et al (1995) had discussed the recent directions in long-term energy modelling. The distinguishing features of long-term modelling such as technological change, shifts in energy supply and dynamic energy-economy interactions have been included in the study. Ramanathan and Ganesh (1995) used an integrated goal programming-AHP model to evaluate seven energy sources usable for lighting in households against 12 objectives representing the energy-economy-environmental systems. Sensitivity analysis on these systems had also been performed. The author(s) (Huang et al 1995) had conducted a literature survey on decision analysis in energy and environmental modelling. The surveyed studies were classified into two categories, namely, decision analysis technique used and by application area and found that the decision making under uncertainty was the most important application technique and energy planning and policy analysis were the most common application area.

Daily Consumption Pattern (DCP) models had been used for the analysis of rate effects (Mika Rasanen et al 1995). The DCP was assumed to consist of the daily rhythm of consumption, the effects of outdoor temperature on consumption and random variations. Victor et al (1996) had analyzed the results of the reform to the Mexican energy sector from 1988 to 1994. Peter J. Spinney and Campbell Watkins (1996) had explained the use of Monte-Carlo simulation techniques for the electric utility Integrated Resource Planning (IRP). Sensitivity analysis and decision analysis had also been
presented. Financial feasibility analysis of box type solar cookers was discussed by Kumar et al (1996) in India using cost functions and expressions for some financial performance indicators had been derived. Able-Thomas (1996) had discussed the benefits and needs for renewable energy technology transfer to developing countries. Also, the author discussed the different models or channels of renewable energy technology transfer for successful dissemination in developing countries. Abdelhak Khemiri-Enit and Mohamed Annabi-Cenaffif (1996) had presented models for energy conservation to be used in energy audits. The author(s) had demonstrated the usefulness of various models relating to the thermal energy (building heat and swimming pool heat), lighting and energy loss due to electrical transformers.

An energy-planning model had been developed using Multiple Objective Programming (MOP) technique for a small, medium and large farms in Punjab, a state in India. The model was having five objectives namely, minimization of energy input, maximization of gross returns, minimization of capital borrowing, minimization of labor hiring and minimization of risk for availability of energy inputs (Surendra Singh et al 1996). The author(s) (Malik and Satsangi 1997) had reviewed the energy planning problems in India at different levels. They had used a computer based mixed integer/linear programming data extrapolation techniques for energy systems planning. A bottom-up simulation model was formulated by Boonekamp (1997) to monitor the energy use of households, called SAVE households. An integrated electric utility planning model, the Resource Policy Screening Model (RPSM) had been used to project acquisitions from independent power producers made by customers of a US power marketing authority (Franklin Neubauer et al 1997). The mathematical model for the Physical Quality of Life (PQL) as a function of electrical energy consumption was reviewed by Alam et al (1998). The equation formulated was used to assess the physical quality of life as a guideline for national planning. Gomes

Michael J. Scott et al (1999) added a stochastic simulation capability to the commonly used integrated assessment model MiniCAM 1.0 to analyze the sources of uncertainty and their relative importance and to help device strategies for depicting and coping with uncertainty. Ram M. Shrestha and Charles O.P Marpaung (1999) had performed an integrated long-term resource planning analysis for the supply- and demand-side effects of carbon tax in the Indonesian power sector. GIS tools were used for renewable energy modelling by Bent Sorensen and Peter Meibom (1999). The model was being applied to various global energy scenarios and constitutes a quite common tool for energy system modelling, assessment and planning. Harry Bruhns et al (2000) had discussed a database for modelling energy use in the non-domestic building stock of England and Wales. Bo Hektor (2000) had discussed the different planning models for bioenergy. An integrated Micro-economic, Multilevel mixed Integer Linear Programming (MILP) staircase model to estimate the aggregate supply of energy crops at the national level in France was presented by Rozakis et al (2001). Sun (2001) had indicated that it was illogical to use Gross National Product (GNP) as an economic variable in the economic output-energy model. Rahul Pandey (2002) had developed a top-down and bottom-up energy policy models for addressing various policies and planning concerns in developed countries. Jayram and Ashok (2003) had presented the integrated energy model for wind, solar PV and diesel power. Christopher W. Frei et al (2003) had formulated a dynamic top-down and bottom-up merging energy policy model. The author(s) (Beccali et al 2003) presented the application of the multicriteria decision-making methodology used to asses an action plan for
the diffusion of renewable technologies at regional level. This methodology helps the decision-maker to select the most suitable innovative technologies in the energy sector, according to preliminary fixed objectives. Claus Huber et al (2004) discussed the features and most important results of the computer model ElGreen, which was used to simulate various promotion strategies for different technologies in all European Union (EU) countries.

3.2 ENERGY SUPPLY-DEMAND MODELS

The different types of energy supply models; energy demand models and energy supply-demand models had been reviewed in this literature in a detailed manner.

The nature and length of the impact that prices and economic activity have on the demand for motor gasoline and distillate fuel oil in the United States had been discussed. Also, a general approach had been implemented to aid any energy analyst in gaining insights into the modelling activity (Noel D. Uri and Saad A. Hassanein 1985). An integrated supply and demand energy planning model for the state of Illinois had been described by Charles and Mark (1987). John D. Sterman et al (1988) had formulated the energy supply model for the estimation of petroleum resources in the United States. Kamal Rijal et al (1990) had formulated a linear multiple regression energy demand forecasting model to project the energy requirements in rural Nepal. Walter C. Labys (1990) discussed the econometric supply models. The econometric methods provide an approach for modelling supply processes where time delays, lags and capital formation were important. Supply models of this type can be statistical or econometric, the later involving distribution lag. Walter C. Labys and Thomas Kuczmowski (1990) had done a survey on the various methods employed in supply modelling and suggestions had been presented to improve the credibility and utility of the
resulting models, especially those intended to support policy analysis. Rong-Hwa Wu and Chia-You Chen (1990) had analyzed energy issues in the short-term for Taiwan using a static input-output (I/O) framework. John Haraden (1991) developed a cost model for magma power generation. This cost model gives the potential cost of magma-generated power. Masood A. Badri (1992) developed a Halvorsen-type mathematical model to analyze the demand for electricity in the residential, commercial and industrial sectors of United States. This model permits consistent estimation of total elasticites of demand for the above-mentioned three sectors. Antonio M. Borges and Alfredo M.Pereira (1992) had framed a two-stage model for energy demand in Portuguese manufacturing sector. In the first stage, a capital-labor-energy-materials framework had been used to analyze the substitutability between energy as a whole and other factors of production. In the second stage, the total energy demand had been decomposed into coal, oil and electricity demands. The two stages had been fully integrated since the energy composite used in the first stage and its price were obtained from the second stage energy sub-model. The role of price changes in energy-demand forecasting as well as in energy-policy had been clearly established by the model.

The residential sector accounts for most of the energy consumption in developing countries. An energy-supply-demand model with respect to developing countries relating to Nepal fuel wood-supply sustainability had been developed by Vishwa B. Amatya et al (1993). The model was based on an end-use/process analysis approach, capable of simulating scenarios to address issues of increasing traditional energy-demand, sustainable supply capacity of the existing energy resources, potential for development of new and renewable energy resources and technology. A linear optimized model of energy-supply and demand to predict and study long-term changes of the system to a village level with a population of 800 people in the North China
Plain had been formulated (Fang Zhen 1993). An econometric model had been used in a disaggregated approach to study the effects of energy demand for the manufacturing sector (1970-1987) respectively relating to UK energy market (Blakemore et al 1994). Duangjai Intarappravich et al (1996) had developed the Asia-Pacific energy supply and demand model to 2010 for high, low and base cases that take into account variations in economic performance, prices and fuel substitution in individual nations and in the region as a whole. Norbert Wohlgemuth (1997) had presented the International Energy Agency’s (IEA) approach of modelling world transport energy demand. Michalik et al (1997) had formulated the structural models to predict the energy demand in the residential sector. Bala (1997) had presented projections of rural energy supply and demand and assess the contributions to global warming. The output of the dynamic system model had been used in the LEAP model and overall energy balances are compiled using a bottom-up approach.

A mathematical model had been developed for the electricity demand based on the concept of Representative Load Curves (RLCs) by Balachandra and Vijay Chandru (1999). Sabine Messner and Leo Schrattenholzer (2000) obtained MESSAGE-MACRO by linking a macro-economic model with a detailed energy supply model. The author(s) had described an automated link of two independently running models. A vector autoregressive models had been developed by Mudit kulshreshtha and Jyoti K. Parikh (2000) to predict the demand for coal in four main sectors in India using the annual time-series data from 1970-1995. The models had been estimated using co integrating VAR framework. Jan Bentzen and Tom Engsted (2001) had used the Auto Regressive Distributed Lag (ARDL) model approach to estimate a demand relationship for Danish residential energy consumption and the ARDL estimates have been compared to the estimates obtained using co integration techniques and Error-Correction Models.
(ECM’S). An attempt had been made by Purohit et al (2002) to estimate the potential of using renewable energy technologies such as biogas plants, solar cookers and improved cook stoves for domestic cooking in India. An econometric model had been formulated using regression method to determine the demand for commercial energy namely, coal, petroleum products and electricity in different sectors in Kerala, a state in India and the models had been refined by using Cochrane-Orcutt transformation algorithm to remove the effects of auto-correlation (Parameswara Sharma et al 2002). Bala and Md Fazlur Rahman Khan (2003) had developed a computer based system dynamics model of energy and environment for Bangladesh to project the energy supply and demand and assessing its contribution to global warming.

3.3 FORECASTING MODELS

Energy forecasting models had been formulated using different variables such as population, income, price, growth factors and technology. The models had been reviewed to determine the energy distribution patterns. The forecasting models were categorized into two groups, namely commercial energy models and renewable energy models.

3.3.1 Commercial Energy Models

Noel D. Uri (1978) had developed a combined econometric model and time-series forecasting model based on Box-Jenkins approach to predict the monthly peak system load for a specific utility by taking account of changes in economic and weather related variables. Noel D. Uri and Stephen P. Flanagan (1979) had formulated a time-series short-term forecasting model to predict the crude petroleum and natural gas production in the United States, using Box-Jenkins approach. Noel D. Uri (1980) had discussed the model for
estimating the undiscovered oil resources in the United States. The regression equation had been used for forecasting the cost of energy conservation in the transportation sector for the period 1980 – 2000 (Hyder G. Lakhani 1981). The regression equations had been used for forecasting the cost of energy conservation in the residential sector for the period 1980-2000 (Hyder G. Lakhani 1982). A forecasting model to predict the minimum fuel requirements whilst minimizing operating costs in a multistage production inventory system had been formulated by Collier and Ornek (1983). Badi and James (1983) had formulated a forecasting model to predict the gasoline consumption by considering the three separate determinants namely, utilization by auto, gasoline efficiency and the stock of cars on the road. Deeble and Probert (1986) had formulated straight-line correlations to predict the annual energy consumption. Newborough and Probert (1987) had discussed the energy-consumption and health-care concerts relating to diet choices. The logistic and energy substitution forecasting models had been used by Bodger and Tay (1987) to predict the electricity consumption in New Zealand using past consumption growth factor.

Sabine Messner and Manfred Strubegger (1987) had presented a Framework to Analyze the Consumption of Energy (FACE), by considering growth factor, economics and technology as variables. John D. Sterman (1988) had described the ability of adaptive expectations and univariate trend extrapolations to explain the energy demand forecasting history. Mahmoud Kaboudan (1989) had developed a non-linear dynamic econometric forecasting model to predict the electricity consumption in Zimbabwe through the year 2010 using 20 years of data. A description of the International Petroleum Exchange Model (IPEM) developed at Massachusetts Institute of Technology (MIT) had been presented (Nazli Choucri and Christopher Heye 1990). Also, they had presented a brief description of system dynamics. Ahmad Faruqui et al (1990) had developed strategic demand forecasting
models for electric utility industries. More sophisticated econometric and end-use models forecasting techniques had been introduced to the utility industry. Wolde-Ghiorgis (1991) had used the industrial energy utilization model to analyze the energy utilization patterns in three factories, namely, cement production, textile manufacturing and food processing industries in Ethiopia. The GDP growth rate had been estimated for Mauritius by analogy with observed growth in more developed countries like Singapore and Hong Kong. The ratio of electricity to GDP is given as empirically determined elasticity coefficients (Harel and Baguant 1991). The modelling of the diffusion of energy consuming durables had been studied using various growth curve models (Ang and Ng 1992). The energy distribution patterns resulted from these models had been compared and taken for the study.

A new method had been presented for evaluating the normalized energy consumption in office buildings in Montreal using the information derived from utility bills (Radu Zmeureanu 1992). The results derived from the new method had been compared with those obtained from the well-known PRISM method, using utility bills from 24 gas-heated buildings and 14 electrically cooled buildings. Loren Lutzenhiser (1992) developed a cultural model of household energy consumption by considering the development of demand-side research, from an early interest in conservation behavior to a later focus on physical, economic, psychological and social models of energy consumption. The ecological foundations of the cultural model and its applications in energy research had been discussed along with some of the analytic consequences of this approach. Stig-Inge Gustafsson (1993) had presented the mathematical modelling of district heating and electricity loads. Hammond and Mackay (1993) had developed a forecasting model to project the oil and gas supply and demand to 2010 for UK. The utilization of electricity within the domestic sector had been examined (Deering et al 1993). An exponential forecasting model had been developed
to predict the Jordan’s energy consumption (Tamimi and Kodah 1993). The model characterizes and quantifies Jordan’s energy needs up to the year 2000. Heffington and Brasovan (1994) had formulated the mathematical model termed as growth curves for the prediction of U.S. crude oil-production.

A forecasting regression model had been developed for the electrical energy consumption in Eastern Saudi Arabia (Ahmed Z. Al-Garni et al 1994), as a function of weather data, global solar radiation and population. Five years of data was used to formulate the energy consumption model. Stepping-regression technique was adopted for the variable selection. The problem of co linearity between the regressors had been investigated by using standard statistical procedures and the model adequacy was determined from a residual analysis technique. Mackay and Probert (1994) had presented a modified logit-function demand forecasting model for predicting national crude-oil and natural gas consumptions based on saturation curve extrapolations for the appropriate energy intensity. Some methodological and application issues related to decomposing national industrial energy consumption into changes associated with aggregate industrial production level, production structure and sectoral energy intensity had been discussed by Ang (1995). He had presented a framework for decomposition method formulation by incorporating three different approaches. Luis Giraldo and Barry Hyman (1995) had derived energy end-use models for pulp, paper and paperboard mills. The applicability of the modelling technique and framework to other industries had also been discussed. A multilogit model for fuel shifts in the domestic sector had been developed by Sudhakara Reddy (1995), using the energy-ladder concept to study the effects of different factors on the selection of an energy carrier for cooking or water heating. They had applied the model to explain energy-carrier choices in Bangalore. Raghavendra D.Rao and Jyoti K.Parikh (1996) had analyzed the demand for petroleum products in India. A Translog econometric model based on time series had
been developed for forecasting. The demand forecasts until the year 2010 had been obtained for the various petroleum products using these models. Tripathy (1997) had discussed the demand forecasting in a utility power system based on the projections for electrical energy consumption up to 2006-'07, released by the Central Electricity Authority (CEA), Government of India. Gonzales Chavez et al (1999) used univariate Box-Jenkins time-series analyses (ARIMA) models to formulate the forecasting model for the prediction of energy production and consumption in Asturias, Northern Spain. Florides et al (2000) used the TRNSYS computer program for the modelling and simulation of the energy flows of the modern houses of Cyprus followed by an energy consumption analysis.

The trend in current and near future energy consumption from a statistical perspective by considering two factors, namely, increasing population and economic development had been discussed by Shiro Kadoshin et al (2000). Samer Saab et al (2001) had investigated different univariate-modelling methodologies for the forecasting of monthly electric energy consumption in Lebanon. Three univariate models were used namely, autoregressive, Auto Regressive Integrated Moving Average (ARIMA) and a novel configuration combining an AR (1) with a high pass filter. Mackay and Probert (2001) had developed a bottom-up technique-forecasting model to predict the supplies and demands of fluid fossil fuels for United Kingdom. Also, a modified logit-function demand model was developed for use with the available historic consumption data. An Oil and Gas Supply Model (OGSM) had been solved and the projections of oil and natural gas supply and demand to the year 2020 for Canada had been presented (Jai Persaud and Uma Kumar 2001). Larry Chuen-ho Chow (2001) had discussed the sectoral energy consumption in Hong Kong for the period 1984-97 with special emphasis on the household sector. Volkan S. Ediger and Huseyin Tatldil (2002) used semi-statistical technique to formulate the forecasting model to predict the
primary energy demand in Turkey and analysis of cyclic patterns. The heating degree-day method had been used by Sarak and Satman (2003) to determine the natural gas consumption by residential heating in Turkey. The different scenarios namely, the base case with no mitigation options, replacement of kerosene and liquefied petroleum gas (LPG) by biogas stove, substitution of gasoline by ethanol in transport sector, replacement of coal by wood as fuel in industrial boilers, electricity generation with biomass energy technologies and an integrated scenario including all the options together in Vietnam had been discussed by using the Long Range Energy Alternative Planning (LEAP) model (Amit Kumar et al 2003). The possible scenario of the development of the gas sector in Poland had been described. An adaptation of the Hubbert model had been implemented to the Polish situation based upon the Starzman modification to estimate the natural gas consumption in Poland (Jakub Siemek et al 2003). Jesus Crespo Cuaresma et al (2004) had studied the forecasting abilities of a battery of univariate models on hourly electricity spot prices using data from the Leipzig power exchange. The specifications studied include the autoregressive models, autoregressive-moving average models and unobserved component models.

3.3.2 Renewable Energy Models

Solar, wind and biomass are accepted as dependable and widely available renewable energy sources. It is the need of the hour to formulate the forecasting and estimation models for renewable energy sources. The various types of renewable energy models were reviewed in the following literature.

3.3.2.1 Solar Energy Models

Habbane et al (1986) had developed a modified solar radiation model to determine solar irradiance from sunshine hours for a number of
stations located in hot dry arid climates. Five sunshine based correlations, namely, Benson et al, Gopinathan, Ogelman et al, Zabara and new quadratic correlation developed by Akinoslu and Ecevit (1990) had been compared for the estimation of global solar radiation. The overall results presented shows that the correlations of Benson et al and Gopinathan fall in the second rank. The actual data for the direct, diffuse and global radiations as measured by Eppley Precision Pyranometers had been analyzed. Also, the correlation between estimated and measured hourly and daily solar fluxes over Bahrain had been presented (Ragab and Som 1991). Paul D. Maycock (1994) obtained the forecasting of international photovoltaic markets and developments to 2010. The author used two scenarios namely “Business as usual” and “Accelerated” for forecasting. Also, the status of all PV module producers had been summarized. Gopinathan and Alfonso Soler (1995) had developed a diffuse radiation models to predict monthly-average, daily diffuse radiation for a wide latitude range. Several years of measured data on global and diffuse radiation and sunshine duration for 40 widely spread locations in the latitude range 36°S to 60°N had been used to develop the model. The oversizing method of estimation in PV systems and the theoretical calculations of the mismatch in PV systems had been discussed by Azmi Z. Taha (1995). A procedure had been formulated by Parishwad et al (1997) to estimate the direct, diffuse and global hourly solar radiation on a horizontal surface for any location in India. An exponential curve, similar to the one used by ASHRAE, was fitted to the collected solar radiation data of six cities from different regions of India for the calculation of hourly solar radiation. The author(s) used three statistical indicators to compare the accuracy of the developed procedure. A number of years of data relating the solar radiation on a horizontal surface, sunshine duration and wind speed in Sudan had been compiled, evaluated and presented by Abdeen Mustafa Omer (1997). The author used Angstrom formula to correlate the relative global solar irradiance to the corresponding relative duration of bright sunshine. The regression
coefficients obtained had been used to predict the global solar irradiance. Also, a radiation map of Sudan had been prepared from the estimated radiation values. The monthly average wind speed and average power had been determined for 70 stations of Sudan by analyzing the routine wind data of these stations. Also, a wind map of Sudan had been prepared. Viorel Badescu (1999) had formulated the correlation to estimate the monthly mean daily global solar irradiation, with bright sunshine hour number or fractional total cloud amount as input for Romania. Shafiqur Rehman (1999) had developed an empirical correlation for the estimation of global solar radiation in Saudi Arabia. Also, he had presented the comparison between the present correlation and other models developed under different geographical and varied meteorological conditions. The comparisons had been made using standard statistical tests, namely Mean Bias Error (MBE), Root Mean Square Error (RMSE), and Mean Percentage Error (MPE) and Mean Absolute Bias Error (MABE) tests.

Meyer and Van Dyk (2000) developed the energy model based on total daily irradiation and maximum ambient temperature. To predict the energy produced by photovoltaic modules under certain meteorological conditions, an energy model can be used. The regression analysis was used to formulate the model and the model was able to predict daily module energy based on the above two parameters only. Zekai Sen and Elcin Tan (2001) had developed a simple parabolic model with three parameters to estimate the hourly, daily and monthly global or diffuse radiation for Northwestern part of Turkey. Wong and Chow (2001) had reviewed the solar radiation models for predicting the average daily and hourly global radiation, beam radiation and diffuse radiation. Seven models using the Angstrom-Prescott equation to predict the average daily global radiation with hours of sunshine were considered. Also, two parametric models were reviewed and used to predict the hourly irradiance of Hong Kong. Amauri P. Oliveira et al (2002) had
formulated a correlation models to estimate hourly, daily and monthly values of diffuse solar radiation on horizontal surfaces, applied to the city of Sao Paulo, Brazil. Safi et al (2002) used higher order statistics to predict the global solar radiation by means of two different procedures. A Monte-Carlo backward ray tracing technique was used to calculate the Angular Shading Factors (ASF) for the determination of time varying diffuse irradiance (Tsangrassoulis et al 2002). Jain and Lungu (2002) developed stochastic models using Box and Jenkins technique for sunshine duration and solar irradiation measured at Sebele, Botswana. The data used consists of the monthly averages and the Julian-days averages of sunshine duration and solar irradiation sequences. A study had been done on the measurement of luminance of day light and solar irradiance from a station in the Asian Institute of Technology (AIT) campus, which is situated in a tropical region. In addition, mathematical models to predict global and horizontal daylight luminance and solar irradiance were presented (Surapong Chirarattananon et al 2002). Raja Peter et al (2002) had formulated the conceptual model for marketing solar-based technology to developing countries. The purpose of the study was to identify the factors that influence the adoption of solar-based technology. The different variables were identified from the examination of the literature in the area of diffusion of technology. Forecasting model to predict the demand on solar water heating systems and their energy saving potential in household sector during the period 2001-2005 in Jordan had been presented by Kablan (2003). A dynamic simulation code (TRNSYS) had been used by Cardinale et al (2003) to investigate a solar plant for hot water production. The author(s) using Life Cycle Savings (LCS) method to evaluate the economic viability of such a plant by considering three conventional fuels namely gas-oil, LPG and electricity. Jain et al (2003) had presented the bivariate models that relate solar irradiation to sunshine duration, and solar irradiation to extreme temperatures for Sebele, Botswana.
3.3.2.2 Wind Energy Models

Wind has been proven as a reliable and cost effective energy source. Technological improvements over the last five years have placed wind energy in a stable position to compete with conventional power generation technologies. The various wind energy models were presented in the subsequent paragraph.

Barry N. Haack (1982) used a computer-operated simulation model, which incorporates wind speeds, residential electricity demands and parameters from the generator, inverter and storage components to determine the amount of energy from a wind-energy conversion system. Panda et al (1990) made a stochastic analysis of the wind energy potential at seven representative weather stations in India. A probability model for the wind data and potential had been developed. The author(s) used Box-Cox transformation to transform the data for all of the stations to a normal distribution. Jamil et al (1995) used Weibull probability distribution function to find out the wind energy density and other wind characteristics with the help of the statistical data of fifty days wind speed measurements at the Materials and Energy Research Centre (MERC) - solar site, Tehran in Iran. Saleh H.Alawaji (1996) had presented the detailed description of the various types of equipments, instruments, site specifications and other technical needs for the wind assessment project in Saudi Arabia. A Cumulative SemiVarigram (CSV) model had been derived by Zekai Sen and Ahmet D. Sahin (1997) to assess the regional patterns of wind energy potential along the western Aegean Sea coastal part of Turkey. This innovative technique provides clues about the regional variations along any direction. The CSV technique yielded the radius of influence for wind velocity and Weibull distribution parameters. The dimensionless Standard Regional Dependence (SRD) functions were obtained from the sample CSV,
which was used to make simple regional predictions for the wind energy or
wind velocity distribution parameters.

Availability of wind energy and its characteristics at Kumta and
Sirsi in Uttar Kannada district of Karnataka, a state in India had been studied
by Ramachandra et al (1997), based on primary data collected at these sites
for a period of 24 months. Wind regimes at Karwar (1952-1989), Honnavar
(1939-1989) and Shirali (1974-1989) had also been analyzed based on data
collected from India Meteorological Department (IMD) of respective
meteorological observatories. A comparison work on various forecasting
techniques applied to mean hourly wind speed was done by Sfetsos (2000)
using time series analysis, traditional linear (ARMA) models, feed forward
and recurrent neural network, Adaptive Neuro-Fuzzy Interference Systems
(ANFIS) and neural logic network. The mean hourly wind speed
data-forecasting model using time series analysis had been presented by
Sfetses (2002). Cluster analysis technique was used by Gomez-Munoz and
Porta-Gandara (2002) to find the local wind patterns for modelling renewable
had discussed the present state of wind energy utilization in Hungary. The
author presented the policy changes of the Hungarian government concerning
the joining of the country to the European Union planned in 2004. Youcef
Ettoumi et al (2003) used first-order Markov chain and Weibull distribution
methods for statistical bivariate modelling of wind using the data wind speed
and wind direction measurements collected every 3-hour at the
meteorological station of Essenia (Oran, a state in Algeria). In addition, a
detailed study had been made on the statistical features of the wind at Oran.
In addition, the Weibull density function was used by Weisser (2003) for the
analysis of wind energy potential of Grenada (West Indies) based on historic
recordings of mean hourly wind velocity. Poggi et al (2003) had discussed an
autoregressive time series model for forecasting and simulating wind speed in Corsica.

3.3.2.3 Biomass and Bioenergy Models

The different types of biomass and bioenergy models were reviewed in the following sections.

A mathematical model had been formulated to find the impact of biogas plants on energy use pattern of rural households in India (Rajeswaran et al 1990). Gardner and Probert (1993) had presented a review of forecasting models for describing the behaviors of landfill-gas-producing sites. A comprehensive approach that considers fuel, fodder and fertilizer relationships had been used to analyze the rural energy system of Karnataka. A linear programming model (Painuly et al 1995) that incorporates these relationships had been used to simulate and study the effects of various policy options on the rural energy system in 2000 A.D. Tani E. Converse and David R. Betters (1995) used stepwise ordinary least-squares regression technique to develop equations to predict yields for short rotation black locust. Kimmins (1997) had discussed the second and third generation hybrid simulation models FORECAST and FORCEE, which evaluate the sustainability of bioenergy plantations. Alam et al (1999) had formulated a quantitative dynamic simulation model as a system study for rural household biomass fuel consumption in Bangladesh. The parameters, constraints and initial values in the model represent present conditions. The model had been simulated to project the status of the system over an extended period. Yasuko Nishigami et al (2000) had proposed a new synthesis method for the estimation of forest area near desserts. A Global Land Use and Energy (GLUE) model had been developed to evaluate the bioenergy supply potentials, land use changes and CO₂ emissions in the world. (Hiromi Yamamoto et al 2000). Haripriya
(2000) had discussed the estimation of biomass and the carbon contained in biomass of Indian forests for the year 1993, using species-wise volume inventories for all forest strata in various states. The use of Geographic Information Systems (GIS) for understanding the geographic context of bioenergy supplies and a regional-scale, GIS-based modelling system for estimating potential biomass supplies from energy crops had been discussed by Robert L. Graham et al (2000). Factors that complicate bioenergy model building had been presented by Roos and Rakos (2000). The author(s) made some recommendations as to how the various aspects namely, the cost structure of energy production, information asymmetry, socioeconomic factors, household economics, strategic considerations and policy uncertainties could be considered in the modelling work to improve model accuracy. Harje Baath et al (2002) had developed a long-term forecasting model based on satellite image for the local assessment of forest fuels. Specht and West (2003) developed a mathematical model to estimate the biomass and sequestered carbon on farm forest plantations in Northern New South Wales, Australia.

3.4 OPTIMIZATION MODELS

Formulation of an optimization model will help in the proper allocation of the renewable energy sources in meeting the future energy demand in India. A review of different kinds of optimization models was presented in the following sections.

Gurfel (1979) had developed an optimization model for the fuel energy balance with higher accuracy. De Musgrove (1984) had used the MARKAL, a linear programming model having total system discounted cost as the objective function and oil conversion and demand as constraints, to analyze minimum discounted cost configurations for the Australian energy
system during the period 1980-2020. A deterministic linear programming model had been discussed by Ellis et al (1985) for the development of acid rain abatement strategies in eastern North America. The maximization of the marginal cost based on environmental constraints was the objective of the model. Satsangi and Sarma (1988) had discussed the possible options for meeting the energy needs of the economy for India for the year 2000-'01. The minimization of the cost was the objective of the model, based on resource, capacity and upper/lower bound constraints. Andy S. Kydes (1990) had discussed the general methodology for flow models and an overview of two Brookhaven Energy System Optimization Model (BESOM) and Timed stepped Energy System Optimization Model (TESOM). Both the models were used to examine interfuel substitutions in the context of constraints on the availability of competing resources and technologies. Pasternak et al (1990) had formulated an optimization model for the economic evaluation of energy conservation projects with an emphasis on initiation time.

Suganthi and Jagadeesan (1992) developed the Mathematical Programming Energy-Economy-Environment (MPEEE) model. The model maximizes the GNP/energy ratio based on environmental constraints, to meet the energy requirement for the year 2010-'11 for India. An overview of energy planning research was presented on implementation of the LEAP model for Tanzania through the use of optimization models in combination with a forecasting model (Luhanga et al 1993). Two models had been developed, in which the first model determines the optimum mix of energy resources at minimum cost. The second model seeks the optimum number of end-use biomass devices and hectares of land to be afforested to minimize the wood fuel deficit. A linear optimization model and a multi-attribute value model had been introduced by Mustafa Tiris et al (1994), to estimate the long-term energy, economy and environment interactions for Turkey. Groscurth (1995) had developed a model, which describes regional and
municipal energy systems in terms of data-flow networks. The model developed provides a highly flexible tool for dynamic and stochastic minimization of primary energy demand, emissions of pollutants and monetary cost. The conventional energy-supply techniques, rational use of energy, demand-side measures and utilization of renewable energy sources were included in the model. A stochastic version of the dynamic linear programming model had been presented by Messner et al (1996). The approach chosen explicitly incorporates the uncertainties in the model, endogenizing interactions between decision structure and uncertainties involved. A cost minimization model for coal import strategy for Taiwan had been developed by Lai Jeng-Wen and Chen Chia-Yon (1996). The model was used to plan future coal import strategy, as well as to study the effect of cost changes by making the sensitivity test. Lehtila and Pirila (1996) had formulated a bottom-up energy systems optimization model to support policy planning in Finland for the sustainable use of energy. The methodology of the Finnish EFOM model had been presented including the description of biomass use for energy, power and heat generation, emissions and the end-use of energy. Also, an important sub model for the energy intensive pulp and paper industries was incorporated in the model.

A Multi Level Optimization (MLO) model had been developed by Sardar (1997) to study the various energy issues such as self sufficiency, conservation and sustainability pertinent to Australia’s situation. The Australian Energy Planning System Optimization Model (AEPSOM) was based on the MLO model. Zhijun Xie and Michael Kuby (1997) had developed a strategic-level, network based investment-planning optimization model of China’s coal and electricity delivery system. MODEST, an energy system optimization model had been described by Dag Henning (1997). The model was applied to a typical local Swedish electricity and district-heating utility and to the national power system. MODEST uses linear programming
to minimize the capital and operation costs of energy supply and demand-side management. Kanniappan and Ramachandran (1998) had developed an optimization model using linear programming, in order to get maximum output of surplus biomass excluding the biomass assigned for fuel and fodder for animals, by suitably allocating the land area for the cultivation of different crops subject to meeting the food requirements for the population with regard to cereals, pulses, oilseeds, sugar and vegetables in Nilakkottai block of Dindigul district, Tamil Nadu, a state in India. Also, the model had taken into consideration of the utilization of the available resources such as human labour, animal power and tractor power in the region mentioned.

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). The model aims at minimizing cost/efficiency ratio and finds the optimum allocation of different renewable energy sources for various end-uses. The constraints used in the model were social acceptance level, potential limit, demand and reliability. The author(s) also focused the study on the performance and reliability of wind energy systems and its effect on OREM model. By considering the above said factors, the OREM model was analyzed for wind energy system, solar energy system and biomass energy system. Iniyan et al (1998) had formulated an Optimal Renewable Energy Model (OREM) for the effective utilization of renewable sources of energy in India for the period 2020-'21, with the objective function of minimizing cost/efficiency ratio and constraints - social acceptance, reliability, demand and potential. The allocation of renewable energy sources for various end uses such as lighting, cooking, pumping, heating, cooling and transportation had been accomplished using the OREM model for the year 2020-'21. A modified econometric model that links energy consumption with the economy, technology and the environment had been validated through comparison with an econometric and
time-series regression model (Suganthi and Anand A. Samuel 1999). The actual requirements of coal, oil and electricity obtained from the modified model were used as input in the Mathematical Programming Energy-Economy-Environment (MPEEE) model. An Optimal Renewable Energy Mathematical (OREM) model had been developed to allocate the predicted renewable energy demand for different end-uses (Iniyan et al 2000). A Delphi study was conducted to find the level of social acceptance in the utilization of renewable energy sources for the year 2020-21. A sensitivity analysis had also been done to validate the OREM model.

An optimization model was developed to determine the optimum allocation of renewable energy in various end-uses in India for the period 2020-21, taking into account commercial energy requirement (Suganthi and Williams 2000). Sensitivity analysis was performed on the model by changing the demand, potential, reliability, emission and employment factors. Renewable energy sources are likely to play a significant role in meeting the future energy requirement of a developing country like India. An Optimal Renewable Energy Model (OREM) that minimizes the cost/efficiency ratio and determines the optimum allocation of different renewable energy sources for various end-uses was presented (Iniyan and Sumathy 2000). The potential of renewable energy sources, energy demand, reliability of renewable energy systems and their acceptance level were used as constraints in the model. A methodology of optimal wind-hydro solution estimation had been developed and subsequently applied to several typical Aegean Sea island cases, in order to define the most beneficial configuration of the proposed renewable station. The author(s) (Kaldellis and Kavadias 2001) used real data, like long-term wind speed measurements, demanded electrical load and operational characteristics of the system components. Cormio et al (2003) presented a bottom-up energy system optimization model using linear programming methodology based on the Energy Flow Optimization Model.
(EFOM) to support planning policies for promoting the use of renewable energy sources. The environmental constraints were also included in the model. An optimization model for a geothermal energy source, based on the theoretical water well of different quality parameters was presented by Drozdz (2003). The model maximizes the net power of the source. The MIND (Method for analysis of INDustrial energy system) method with feedback loops had been developed for multi-period cost optimization of industrial energy systems, taking care of both energy and material flows (Mei Gong 2003). Ashok Kumar Sinha and Surekha Dudhani (2003) had presented a linear programming based methodology for allocating optimal share of renewable energy resources with varying technological and cost coefficients. The role of government and private agencies in promoting the growth of small hydropower had also been discussed.

3.5 ENERGY MODELS BASED ON ARTIFICIAL NEURAL NETWORK (ANN)

Intelligent solutions, based on Artificial Intelligence (AI) technologies to solve complicated practical problems in various sectors are becoming more and more nowadays. AI-based systems are being developed and deployed worldwide in various applications, mainly because of their symbolic reasoning, flexibility and explanation capabilities.

Fuzzy theory had been applied to the logistical optimization of the supply and demand sectors in order to assess the relative importance or degree of association between the supply and demand determinants (Sanders et al 1993). A two layered feed forward artificial neural network forecasting model had been developed to relate the electric energy consumption in the Eastern Province of Saudi Arabia to the weather data, global radiation and population. Seven years of data was used for model building and validation.
The model adequacy was established by a visual inspection technique and the chi-square test (Javeed Nizami and Ahmed G. Al-Garni 1995). Michalik et al (1997) used linguistic variables and fuzzy logic approach for the development of mathematical model to predict the energy demand in the residential sector. Abductive network machine learning had been proposed by Abdel-Aal et al (1997) as an alternative to the conventional multiple regression analysis method for modelling and forecasting monthly electric energy consumption of Eastern Saudi Arabia in domestic sector. A neural network approach was formulated for the wind speed prediction and compares its performance with an autoregressive model (Mohamed A. Mohandes et al 1998), after observing the statistical characteristics of mean monthly and daily wind speed in Jeddah, Saudi Arabia. The autocorrelation coefficients were computed and were found compatible with the real diurnal variation of mean wind speed. Also, the stochastic time series analysis was found to be suitable for the description of autoregressive model that involves a time lag of one month for the mean monthly prediction and one day for the mean daily wind speed prediction. A fuzzy multiobjective linear programming approach to solve the energy resource allocation was presented by Chedid et al (1999). For this, nine energy resources, and six household end-uses were considered. In addition, the sensitivity analysis on the energy systems was performed. Soteris A. Kalogirou (2000) had used Artificial Neural Network (ANN) technique for the estimation of heating-loads of buildings and for the prediction of energy consumption of a passive solar building. Multiple hidden layer architecture was used in the modelling. Soteris A. Kalogirou and Milorad Bojic (2000) had developed a model based on Artificial Neural Network (ANN) for the prediction of energy consumption of a passive solar building. A multilayer recurrent architecture using the standard back-propagation learning algorithm had been applied to develop the model. Wavelet transform and neural network technique were used to formulate the model for short-term electrical load forecasting (Yao et al 2000). A fuzzy based multiobjective analysis was
made by Agarwal and Singh (2001), for the energy allocation for cooking in Uttar Pradesh households in India. The economic, environmental and technical concerns were the main objectives included in the model. Atsu S.S.Dorvio et al (2002) used Artificial Neural Network (ANN) methods to estimate solar radiation by first estimating the clearness index, Radial Basis Functions (RBF) and MultiLayer Perception (MLP) methods. A neural network based energy consumption model had been developed for the Canadian residential sector (Merih Aydinalp et al 2002). Che-Chiang Hsu and Chia-Yon Chen (2003) collected empirical data to formulate an Artificial Neural Network (ANN) model to predict the regional peak load of Taiwan. Metaxiotis et al (2003) had given the overview of AI technologies as well as their current use in the field of Short Term Electric Load Forecasting (STELF).

3.6 EMISSION REDUCTION MODELS

Jae Edmonds and John Reilly (1983) had formulated a long-term global energy-economy model of CO₂ release from the utilization of fossil fuels. They had projected that if the same trend continues; there will be tremendous amount of emission in the future. David B. Reister (1984) had presented how a simple model could be implemented in conjunction with an elaborate model to develop CO₂ emission scenarios. The global atmospheric CO₂ and the temperature variation that would result from various future CO₂ emission scenarios had been determined using a coupled climate-carbon cycle model by Danny Harvey (1889). Danny Harvey (1990) had estimated the impact on atmospheric CO₂ emission-reduction strategies, using the coupled climate-carbon cycle model. Leif Gustavsson et al (1992) used an end-use accounting model to identify the energy systems, which significantly reduce emissions of acidifying gases and CO₂ from non-mobile sources for Western Scania, Sweden. Kamiuto (1994) arrived a simple global carbon-cycle model
for the forecasting of future atmospheric CO\textsubscript{2} concentrations based on the previous theoretical model for a global carbon cycle considering CO\textsubscript{2}-fertilization effects of land biota. Kamiuto (1994) developed a simple global carbon-cycle model with three main reservoirs, namely, the atmosphere, biosphere and the oceans. It includes a description of CO\textsubscript{2}-exchange processes between the reservoirs, disregarding the interior transfer processes within the biosphere and the oceans. The model was utilized to reconstruct the time history of CO\textsubscript{2}-emission rates due to deforestation and changing land use during the past 200 years and to estimate the CO\textsubscript{2} transfer rates between the reservoirs around 1980. A set of models for global carbon cycle, world population and atmospheric CO\textsubscript{2} had been proposed by Kamo S. Demirchian and Karina K. Demirchian (1996). Dispersion-modelling study of SO\textsubscript{2} concentrations in Gebze, Turkey had been conducted by Tiris et al (1996). They had predicted the winter average SO\textsubscript{2} contributions to the air quality over Gebze by using the emissions, meteorological and topographical data that were loaded on the USEPA-approved ISCLT Model. Gert Tinggaard Svendsen (1998) had formulated a general CO\textsubscript{2} regulation model for Denmark. This model may guide the future energy policies in other countries as well.

A regional engineering model for assessing space heating energies and related green house gas emissions for North Karelia, Finland had been presented. The objective of the modelling was to improve the quality and quantity of heating energy and emission data, especially for the benefit of local decision making (Snakin 2000). Some of the basic requirements of useful greenhouse gas reduction model were reviewed by Mark (2000). Kris R.Voorspools and William D.D’haeseleer (2000) formulated an evaluation method for calculating the emission responsibility of specific electric applications. In addition, a tool and a methodology had been developed to simulate and evaluate electric demand- and supply-side options.
A multiobjective programming approach integrated with a Leontief inter-industry model had been used to evaluate the impact of energy conservation policy on the cost of reducing CO\textsubscript{2} emissions and undertaking industrial adjustment in Taiwan. An inter-temporal CO\textsubscript{2} reduction model, consisting of two objective equations and 1340 constraint equations were constructed to simulate alternative scenarios (George J.Y. Hsu and Feng-Ying Chou 2000). Matthews (2001) had formulated a standard methodology for evaluating the energy and carbon budgets of bio-fuel production systems, with emphasis on wood fuel production from short rotation coppice. A time-series analysis of energy related carbon emissions and their relationships with energy consumption and GNP in Korea had been studied by Ki-Hong Choi and Ang (2001) from 1961 to 1998. Ricardo Cunha da Costa (2001) had compared some Brazilian energy and CO\textsubscript{2} emission scenarios in 2010 in order to verify how far model structures influence findings and decisions. Marian Leimbach (2003) analyzed the equity issues that frame decisions on emission rights allocation, based on the ICLIPS model.

The different energy models were reviewed globally. The following important factors in the energy utilization such as gross income, gross output, profit, energy quantity, GNP/energy ratio, energy performance, energy production were considered as the objective function of linear programming models. Also, it was identified that technology, efficiency, supply, demand, employment and resource availability were used as constraints in the model. It was observed that the behavioral or econometric models and the macro-statistical single-entity models reflect the overall aggregate characteristics of energy supply and consumption and are oriented towards forecasting. It was observed that the linear programming models of different types can be used profitably in all the periods and the econometric models are best suited to the short- and medium-term forecasting. In addition, it was
noticed that the efficiency and cost factors, which were identified to be critical parameters in the objective function formulation. It was identified that the energy–economy models help in understanding the way in which energy–economy interactions work. In addition, they enable the planners to predict and plan the future. It has been concluded that the models serve to promote discussion and formulation of policies, which are appropriate to the situation.

It has been identified that the Artificial Neural Network (ANN) can be used in the energy demand forecasting and the fuzzy logic for energy allocation in the country. In the present ANN forecasting model, the input variables such as past consumption data, GNP and population were used. In the previous models these variables had not been used collectively.

In the present Optimal Electricity Allocation Model (OEAM), minimizing the unit cost of the energy systems was the objective function, the potential, demand, efficiency, emission level and carbon tax were the constraints. Introducing the carbon tax as a constraint was the uniqueness of the model, which will control environmental pollutants in the country. Also, it was observed that the new energy technologies such as OTEC, tidal, geothermal, MHD, tidal, solid waste and fuel cell had not been used in the energy planning models so far for the power generation and it was decided that these new energy technologies have to be included in the present research study.