2. LITERATURE REVIEW

2.1 3-E Goals

A number of studies have been carried out for energy scenario of India. The Institute of Electrical Engineers Japan (IEEE) has analyzed energy problems of India in 2001. Their report presents the energy security and solutions for meeting the future energy needs. Reliance review of Energy Markets in 2003 also discusses about global and regional energy issues at length. They have proposed National Energy Modeling System (NEMS) for achieving 3-E goals. Draft Report of the Expert Committee on Integrated Energy Policy under Planning Commission, Govt. of India elaborates on the national energy policy decisions. In USA, National Energy Modeling System, Department of Energy, has made integrated energy model for their country.

Samarakao [76] has compared results of two different optimization techniques for a combined wind and solar plant. Hernandez [28] has studied economic-environmental criteria for sanctioning the substitution of fossil fuel-fed energy systems by renewable energy systems. Chedid and Saliba [12] worked on optimization and control of autonomous renewable energy systems in the year 1993. Sinha and Kandpal [81] have analyzed optimal mix of technologies for rural India, the cooking sector.

Srinivasan and Balachandra [82] carried out micro level energy planning for India through a case study of Bangalore north taluk. Ramakumar et al [69] studied the economic aspects of advanced energy technologies. Akella, Sharma, and Saini [02] discussed optimum utilization of renewable energy sources for a remote area.


For a breath of fresh air, the World Bank report (2005) on climate change presents energy-environment linkages. Pachauri [55] addressed the challenges of energy...
Mourelatos et al [49] examined the impact of CO₂ reduction policy on the strategic planning of the energy sector together with the conflicts between economic and environment goals influencing the penetration of renewable energy sources. In the linear programming model, energy flows were optimized with respect to the system's economic efficiency. Chedid et al [12] provided a methodology for the optimization of an electrical distribution network when upgraded by renewable energy technologies. A multi-objective linear programming model was used in conjunction with fuzzy logic.

2.2 Optimization Models

Optimization models are prescriptive rather than descriptive and tell the user how to make the best of a given situation in relation to a predefined goal. The optimization model has a goal or an objective represented by a function usually referred to as an objective function that is to be maximized according to the given alternatives and the imposed constraints. As opposed to accounting models, optimization models have several degrees of freedom and therefore there is not only one feasible solution to these problems, but also many: infinitely many in fact. The objective is to identify the best from all these solutions. The output of an optimization model should be the best way of accomplishing a goal, rather than a prediction. So instead of being "what if" tools, they are "how to" tools. Optimization models are most useful in situations
when the problem is to choose the best from a set of well-defined alternatives. This applies in particular when the problem relates to technology choice.

Energy models are, like other models, simplified representations of real systems. Models are convenient tools in situations where performing tests or experiments in the real world are impractical, too expensive or out-rightly impossible. Computer models offer several advantages over mental models and thought experiments:

(a) They are explicit, their assumptions are (should be) stated in the written documentation and open for review
(b) They compute the logical consequences of the modeler’s assumptions
(c) They are comprehensive and able to interrelate many factors simultaneously.

Energy system models are thus useful, as they depict immensely complicated systems that are beyond the ability of the human brain to comprehend and understand. These models can be used to perform comprehensive calculations and system analysis. They can help identify market subtleties and unveil system dynamics that would otherwise have gone unnoticed. Furthermore, the assumptions that form the base of the models are explicitly and unambiguously stated (unlike thought experiments and mental models), so that they are open for critique and review. Further this allows for risk, hedging strategy and sensitivity analysis for policy makers and investors.

There are general characteristics, which are shared by all models. For instance, any model will always be a simplification of reality and includes only those aspects that the model developer regarded important at that point of time. Grubb et al [25] mention that any model dealing with future situations unavoidably makes use of estimates and assumptions which may or may not turn out to be valid under certain circumstances, but will at the time of application inevitably be uncertain. The problem with classifying energy models is that there are many ways of characterizing the different models, while there are only few models—if any—that fit into one distinct category. An example of a classification is given by Hourcade et al [29], who distinguished three important ways to differentiate energy models, namely (a) purpose of the models, (b) their structure, and (c) their external or input assumptions. On the other hand, Grubb et al [25], use six dimensions to classify energy models, including (a) top-down vs.
ottom-up (b) time horizon (c) sectoral coverage (d) optimization vs. simulation techniques, (e) level of aggregation, and finally (f) geographic coverage trade and packaging. Other ways of classification include: the applied mathematical techniques, the degree of data intensiveness, the degree of model complexity and the model flexibility. The following section gives an overview of the various types of energy models, which are applied for energy planning.

Presently, the software's available for optimization are LINDO, LINDO API, LINGO, HOMER, VIPOR, TORA, etc., out of which LINGO 10.0 version has been reported to be the most traditional package for solving linear, integer and quadratic optimization models. The software offers the most comprehensive tools for studying the inner workings of the revised Simplex Method used to solve linear optimization models. Its unique features are its goal programming, parametric analysis and efficient solution of quadratic programs. Optimization and simulation models have been applied to energy system modeling. Samarakao et al [76] demonstrated the use of optimization and embedded simulation to establish the least cost configuration of an isolated wind, photovoltaic and diesel system with battery backup. The model was implemented using two different non-linear optimization packages. Hernandez [28] presented a thermo-economic optimization and cost-benefit balance to sanction the substitution of fossil fuel fed energy systems by renewable energy sources. The model was analyzed on economic-environment criteria. Sinha and Kandpal [81] have developed a linear programming model for determining an optimal mix of technologies for domestic cooking in the rural areas of India. A mathematical model involving common sources (including biomass, commercial and solar) and commercially available technologies are formulated along with the detailed techno-economics of the different energy conversion routes. Similar exercise Suganthi et al [84] has been done for irrigation and lighting. Minimizing cost was chosen as the objective in all cases. Suganthi and Samuel [84] have developed a macro level energy planning model which maximized the Gross National Produce and energy ratio. It determined the optimum allocation of commercial and renewable energy for emission reduction. Iniyan and Jagadeesan [36] have proposed a renewable energy optimization model for India. The model considers the allocation of renewable energy sources in different end-uses. It optimized the cost and efficiency of the system. Joshi et al [40] have made a decentralized energy planning model for optimum resource
location with a case study of the domestic sector of rural area in Nepal. Suganthi and Amuci prepared optimal energy forecasting model for economy-environment match. Iniyan and Jagadeesan observed effect of wind energy system performance in optimal renewable energy, an analysis in which viability of wind energy as compared to other renewables has been discussed. Suganthi and Williams for renewable energy in India proposed a modeling study for the period 2020-2021. In this model they suggested only renewable energy without considering the conventional energy sources. Dantzig did programming and extensions by using C language for better energy mix. Matters applied reduction of integer polynomial programming problems to Zero-One Linear Programming problems for solving energy demand-supply.

M R Das had developed a multi-objective linear programming (MOLP)-based dynamic optimization model to analyze the renewable energy policy for Tamil Nadu, a state in India. Suganthi and Jagadeesan had developed the mathematical programming energy-economy-environment (MPEEE) model. The model maximizes the gross net product (GNP)/energy ratio based on environmental constraints, to meet the energy requirement for the year 2010-2011 for India. An overview of energy planning research was presented by Luhanga et al on implementation of the long-term energy alternative planning (LEAP) model for rural area in Tanzania through the use of optimization models in combination with a forecasting model. Raja et al had presented an energy planning optimization model using linear programming (LP) technique for sustainable agriculture development in the Chellampatti block of Madurai district, Tamil Nadu, a state in India. The model had been developed based on the availability of various energy sources in the block and the requirements of various human and agricultural activities. Kanniappan and Ramachandran had developed an optimization model using LP, in order to get maximum output of surplus biomass 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 the utilization of the available resources such as human labor, animal power and tractor power in the region mentioned. A modified econometric model that links energy consumption with the economy, technology and the environment has been validated through comparison with an
econometric and time series regression model by Suganthi and Samuel [84]. The actual requirements of coal, oil and electricity obtained from the modified model have been used as input in the MPEEP: model. A Delphi study has been conducted by Iniyan et al [37] to find the level of social acceptance in the utilization of renewable energy sources for the year 2020-2021. A sensitivity analysis has also been done to validate the OREM. Cormio et al [13] had proposed a bottom-up energy system optimization model in order to support planning policies for promoting the use of renewable energy sources. LP optimization methodology based on the energy flow optimization model (EFOM) was adopted, detailing the primary energy sources exploitation (including biomass, solid waste, process byproducts), power and heat generation, emissions and end-use sectors. The proposed methodology was applied to a case study of the Apulia region in Southern Italy. The test results proved that the regional policy, aimed at satisfying the increasing demand for electricity and heat in the region, can be supported mainly by combined cycle installations and with less effort of wind to power, waste-to-energy and biomass exploitation and industrial cogeneration systems. Devdas [19] presents an overview of data for the socio-economic system of the target area, which are available from literature as well as from district, block, and village level records and presents an LP model for optimum resource allocation in a rural system. The objective function of the LP model aimed at maximizing the revenue of the rural system where in optimum resource allocation was made subject to a number of energy and non-energy related relevant constraints. The model presented in the paper is for micro-level planning of the rural energy system along with a detailed comparison of data for primary and secondary sources. A model estimating the output of the rural system is also presented. Model quantifies the major products and byproducts of different sectors of the rural economic system and also allocates the energy resources to different sectors of the rural economic system. Nakata et al [53] used optimization modeling to study efficient ways to integrate renewable energy systems to provide electricity and heat in rural Japan. The model provides minimum cost system configuration and operation taking into account hour-by-hour energy availability and demand. In the model, renewable electricity was provided by a combination of wind, photovoltaic, and biomass. Heat required was supplied from petroleum, liquefied petroleum gas (LPG), and geothermal heat pumps (GHPs). Optimal planning of rural medium voltage distribution networks is done by Nahman and Spiri [52]. The model
suggested that for selection of main initial parameters and timing of the reconstructions of rural distribution networks in long-term planning was to meet the increasing load demands with minimum total present worth cost. The model incorporated capital and exploitation costs as well as the costs due to undelivered energy and load curtailments. The optimal investment policy was determined using a constrained dynamic programming technique which indicates the best choice among possible options while taking into account all relevant technical criteria and common-sense rules.

Malik and Satsangi [48] had reviewed the energy planning problems in India at different levels. They had used a computer-based mixed integer linear programming (MILP) data extrapolation technique for energy systems planning. They have showed how the model was suitably scaled for obtaining the optimal mix of energy resources and technologies for the Wardha District (Maharastra State, India) using a computer-based MILP technique. Nagel [51] used MILP to determine an economic energy supply structure based on biomass. The preferred field of application was the rural area because of the reasonable relation between the potential of biomass and the transportation distances that have a great influence on the economic viability. A MILP model based on the dynamical evaluation of economic efficiency could help to find the most economical and ecological supply structure. The model was developed for three different types of operating companies. The influences of different parameters on the target function could be analyzed by defining scenarios and by running sensitivity analyses. The results showed that the energy prices have the greatest influence on the economy. A technique for computing the actual output energy of different combinations of wind–diesel engine system was developed by Zefawy and Abou El-Ela [93]. A non-linear programming technique was used to optimize the combination of wind–diesel generation units to meet the load demand. The suggested technique was applied numerically to choose the most economical model from the different wind energy machines installed at a site in Egypt on the Mediterranean coast. An optimal generation procedure for the economical wind diesel engine system of a constructed village at the considered site was introduced. As a conclusion of the study, the share of wind energy and diesel engine energy to meet a specified load at minimum cost within the system operation constraints were deduced. Singh et al [78] developed an energy-planning model using multiple objective programming (MOP) technique for small, medium and large farms in Punjab, a state in
India. The model had 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. Decentralized models have been applied for block level as well as village level planning in India. An MIP model for technology selection and an LP based goal programming model at village level were developed by Deo et al. [18] at Indian Institute of Management Ahmedabad, IIMA. The models were applied to block and village level, blocks included for planning were Shahapur in Karnataka district, Dhanu block in Thana district in Maharashtra. A rural energy development programme titled Urja Gram undertook energy planning exercise at Rampar village in India. The optimal solution consisted of decision on systems selected, allocation of energy from an energy system to an end-use in a given period and costs due to optimal solution. Energy planning exercise and the application of model demonstrated that the case study was used effectively to understand the exact implications of various interventions so as to select policies to be pursued in activating village energization process. Audsley and Annetts [04] in their paper details the LP model used to optimize the profitability and determine the optimal planning of processes in a bio refinery factory, the complexities of defining how processes affect products and by-products and how this is used within the LP. An example of LP matrix and solution was used to illustrate the formulation and understanding of optimal planning process. The work was the culmination of 3 years funded projects to assess the potential of such centralized and integrated systems of crop processing as alternatives to more conventional separate harvesting and milling processes. Literature review shows isolated attempts to develop and use an energy plan separately at the district, block, panchayat and village level. Often it is based on the estimated supply and demand. The decentralized planning should satisfy as stated above cost of supply maximization of efficiency and fulfill social implications like job creation, participation of poor, or meeting the needs of poor, reducing green house gases (GHG) emissions. But an integrated approach is missing. The question that raises interest here is the criteria for selection of optimal scale or mix? What is the mix and how it can be integrated together for a given scale of centralized energy planning.

The Energy Research Institute (TERI) and the University of Waterloo (UW) undertook a joint research project (1994-1997) aimed at developing participatory planning and
nervention design methodologies and tools to facilitate public participation and feature a
meaningful role for women in rural energy planning. This study presents the policy
applications and recommendations. A new method for local energy planning (village)
as proposed by Reece [08] which considers several constraints—context-related issues,
and expressed in monetary at least quantitative, its application to local region technology
related issues, focus on small scale energy (renewable) systems data availability. The
ext part of the study reveals that the work is restricted to the selection of new energy
systems from production of proper energy forms in order to meet increased energy
demand. The demand was actually the desire for certain energy services. The method
described in this uses a decision support tool that does not decide for the energy planner
which actions to take. The study concludes that the planners themselves must make the
ultimate decision. Biswas et al [09] proposed an integrated ecological, economic and
social model to assist sustainable rural development in villages in Bangladesh. In the
model, renewable energy technologies create income-generating activities for landless
and marginal farmers and indoor air pollution for women in the household from cooking
with poor-quality fuels. Because of their high capital costs, the model proposes an
extension of the well-known micro-credit approach developed by non-government
organizations (NGOs) such as the Grameen Bank and The Bangladesh Rural
Advancement Committee (BRAC). The study states that with the assistance of an
external agency composed of NGOs, business, government and university
representatives, group of villagers can form village organizations, comprising
cooperatives or other forms of business. They borrow money from a bank or NGO and
purchase renewable energy technologies such as biogas, solar or wind, depending upon
the location. By selling energy to wealthier members of the village, the village
organizations would repay their loans, thus gaining direct ownership and control over the
technology and its applications. The Rehovot approach to rural planning and
implementation, first developed in Israel, has subsequently been refined for application to
the myriad problems of rural areas of developing countries. The method is based on
integrated rural management strategies; ensuring that agricultural changes are paralleled
by the development of secondary and tertiary sector activities and of appropriate social
and administrative institutions. The role of ‘bottom-up’ planning systems is particularly
highlighted.
The holistic approach to planning is illustrated by actual case examples by Weitz [89]. The details and results of an energy model of a non-electrified rural village are given by Howells et al. [30]. The model represents a hypothetical, but a typical, South African rural village. The model was developed with MARKAL, modeling and optimization tool. The primary objective of the modeling process, in the approach taken, was to ascertain the least-cost method of meeting the energy needs of the village, under various constraints and user-defined bounds. The study also presents the details of the modeling project by first focusing on integrated energy-environment-economic models in general and the limitations of these models and then going on to describing the limitations associated with rural energy modeling. Finally, it focuses on the model structure itself and the results obtained. Decentralized models have also been applied for micro-level energy planning. A MILP model for technology selection at village level and a LP-based goal programming model were developed at Indian Institute of Management, Ahmedabad by Kanadia [43]. This study was based on use of MARKAL for different cost and tax scenarios targeted towards penetration of renewable energy technologies in the power generation sector of India. Focus of this study has been more towards economic and financial aspects rather than the technology side. Ravindranath and Hall [71] in the book ‘Biomass, Energy and Environment’ explain the important aspects of utilizing bio-energy potential in India. The authors emphasize that bio-energy has the potential to provide a decentralized village level and self-reliant energy system to meet needs in a sustainable and environmentally sound way. They also explain the approach of implementation of rural bio-energy centers (RBC) scheme and large-scale bio-energy systems. The approach suggested here aims to meet all rural energy needs in India. Murphy states that there is renewed optimism about the potential for leapfrogging in the rural energy sector of East Africa. The study identifies economic, social, political, and cultural factors limiting the ability of rural people to rapidly switch into using and/or supplying these technologies. He finally concludes that in designing technology dissemination or energy supply projects, planners must thoroughly account for the capabilities existing in rural areas. Zhen [94] has drawn the network diagram of an energy-supply and demand system, as well as a linear optimized model of energy integrated in the economy. The target was the least cost of energy supply and the best energy-supply structure. A supply demand model was built to predict and study long-term changes of the system. The two models are combined and applied to a village with a population of 800 people in the North China
Plain. Results of computer simulation showed that in the base year (1990) if energy transformation devices are properly installed, the cost of supply system will reach the lowest level while meeting the energy demand and saving of energy. The geographical boundaries of a block can provide the necessary land for producing food, fuel, fodder and fertilizer for sustainable development. Block level energy planning has been attempted in many cases but not implemented; it deals with planning for meeting all the basic needs of a block covering 80-90 villages. A MOP-based approach was adopted for block level planning by Jana and Chattopadhyay [39]. Narayangarh block of Midnapore district in India was selected for the study. In this study, the energy allocation model was initiated with three separate objectives for optimization; minimizing the total cost, minimizing the use of non-local sources of energy and maximizing the overall efficiency of the system. The study aimed at formulating policies for block level energy planning involving all the major sectors of energy use in an integrated form at regional level (block). Multi-objective fuzzy linear programming (MOFLP) model, was used in a compromising decision support framework. As a conclusion of the study it is shown that MOFLP is a more rational alternative to single objective LP model in rural energy planning. Deo et al [18] explains the energy planning exercise adopted by Maharashtra Energy Development Agency (MEDA) for Dhanu block in Thane district in Maharashtra state in India. The focus of planning was fixed on augmenting the energy supply from varied sources, local as well as central, subject to understanding the limits of the available purchasing power with local population. The objective of the block energy planning was aimed at planning for future needs of the block at minimum energy supply costs. Based on field studies, energy plan was prepared for a period of 5 years (1990–1995).

Environmental intervention scenarios for GHG emissions reduction in case of Indian power sector have been studied by Ghosh et al [24]. An overall energy system framework was used for assessing the future role of renewable energy in the power sector under baseline and different mitigation scenarios over a time frame of 35 years, from 2000 to 2035. The methodology used an integrated bottom-up modeling framework. The paper also assessed the clean development mechanism (CDM) investment potential for power sector renewables. It outlined specific policy interventions for overcoming the barriers and enhancing deployment of renewables for the future. Biswas et al [99] proposed an integrated ecological, economic and social model to assist sustainable rural development
in villages of Bangladesh. In the model, it is shown that renewable energy technologies reduce environmental problems, like deforestation and indoor air pollution from cooking with poor-quality fuels. The study by Eroglu et al. presents a brief review of energy use patterns in three economic sectors, namely, residential, industrial, and transport. This paper forecasts the growth in energy demand and corresponding emissions for the year 2020 for these three sectors by using a model based on the end-use approach. The energy savings from the energy conservation strategies, such as energy efficiency improvement and energy demand management, are assessed and also the implications on electricity generation expansion planning are examined. The integrated resource-planning (IRP) model was used to find the least-cost electricity generation expansion plans. The effects of energy conservation options are analyzed using a scenario-based approach. The results of analysis reveal that the improvement of public transportation can reduce future energy requirements and CO₂ emissions in 2020 by 635 thousand ton of oil equivalent (toc) and 2024 thousand ton of CO₂ equivalent. The paper concludes that if all options are simultaneously implemented, the potential of energy savings and CO₂ mitigation in 2020 are estimated to be 1240 thousand ton and 3622 thousand ton of CO₂ equivalent, respectively. The interconnections between energy, agriculture and environment in rural India are analyzed using a systems perspective by Pariyut et al. [56]. Rural areas of developing countries use biomass for fuel, fodder, fertilizer and other purposes, and with this purpose the paper estimates the fuel fodder-fertilizer relationships for optimal biomass allocation. The allocation is explored using a LP model, which was validated by simulating it using data for the year 1990-1991. The model was then applied for the year 2000, and several scenarios are generated to obtain answers to various policy questions. The results show that it is necessary to increase fertilizer consumption, to increase efficiencies of cooking stoves, to improve livestock feed, and/or to decrease population growth for maximizing the revenue generated in the rural system of India. Technical, economic, and environmental implications were analyzed for an evaluation model for developing local renewable energy sources by Yue and Wang [92]. This study evaluated wind, solar, and biomass energy sources in a rural area of Chigu in southwestern Taiwan. The approach adopted evaluates local potentials of renewable energy sources with the aid of a GIS according to actual local conditions, and allows the assessment to consider local potentials and restrictions such as climate conditions, land uses, and ecological environments, thus enabling a more-accurate assessment than is possible with evaluations.
on an approximate basis. Chinese cities are experiencing major environmental effects from fossil fuel-based energy consumption for mainly in residential and, increasingly, urban transportation uses. Sadownik and Jaccard [74] proposes community energy management (CEM) a sustainable energy strategy, which looks at shaping the built environment, and designing urban services in consideration of energy production, distribution and use, which could affect both the long-term demand for energy and the type of energy supplied. This study explores CEM in a Chinese context by analyzing trends in land-use planning, urban transportation and residential energy, and then suggests CEM strategies that would be appropriate in directing urban development towards a more sustainable energy path. A spreadsheet model is used to evaluate aggregate energy-related emissions in the year 2015 that result from two alternative scenarios of urban growth throughout China. The model focused on how energy demands; residential energy technology penetration and transportation mode choices are affected by factors of density and mix of use in neighborhood development. Reddy et al [72] proposed development focused, end-use oriented, service directed (DEFENDUS) approach to energy planning. The DEFENDUS method has been used and described to demonstrate its applicability and was not confined to a particular region or source of energy. The study included: electricity for five states of India, petroleum products for the country as a whole, biomass for the state of Karnataka and a composite energy scenario for Karnataka state involving integration of all the currently used sources of energy. In every case, the total energy usage is disaggregated between the existing categories of users according to their end-uses. Then depending on the goals selected and the strategies that could be adopted to achieve them, growth rates for each category of users are used to estimate the number of users in future years. Improvements in the efficiency of end-use devices and/or substitution of energy sources are considered, to determine the possible reduction in the category-wise unit energy usage, and the corresponding energy requirement was estimated. The electricity plan for state of Karnataka comprises future demand estimation as well as the comparative costs of various supply/saving options. In oil scenarios for India, the focus was mainly on demand management through modal and carrier shifts, with emphasis on middle distillates. The biomass strategy for Karnataka included both demand and supply side measures. The energy-environment technology packages are rarely used at local, block and district level energy planning. Thus it is necessary to develop criteria and identify environmental factors that need to be
incorporated during DEP. The literature review of this section shows that there is a need to develop an approach and methodology to incorporate all the relevant environmental factors in DEP. IRP is an energy planning approach to identify the mix of centralized, decentralized renewables and efficiency improvements that will meet the demand for increasing energy services at least cost or least environmental impact. Solar, wind and biomass are accepted as dependable and widely available renewable energy sources. The approach involves using the local available energy resources cleverly or in other words using the optimum mix of the resources to meet the needs of rural people. Such factors are mainly incorporated in resource energy planning. The various types of renewable energy resource models have been reviewed in the following section. Energy-planning attempts for rural areas make use of a mix of locally available renewable resources with some commercial resources to cater to the energy needs of the population.

Fernandez et al [22] have attempted to assess the level of energy resource consumption inequality in a typical hilly rural Indian village (Kanvashram village, Pauri Garhwal district, Uttaranchal, India). The Gini coefficient of inequality, a measure of inequality in the field of econometrics has been applied for this assessment. The population is segregated into different categories based on their income levels and certain socioeconomic criteria, which are also likely to exercise an influence on consumption levels of energy. The results of the analysis are then discussed in the light of the findings. To demonstrate the dependence of energy consumption on available resources, Bowonder et al [11] have conducted a study of eight rural communities in India. The study indicates that levels of energy consumption vary widely among the communities and that consumption depends on socioeconomic and agro climatic factors. Irrigation was the most significant factor influencing energy consumption and demand. Fuel wood was used not only by the low-income households but also by the higher-income households. There is a progressive trend towards monetization of fuel wood, animal wastes and agricultural residues. Energy planning for rural communities should be location and household specific, and disaggregated information should be generated for this purpose using baseline surveys. Dendukuri and Mittal [17] showed that for effective energy planning, it is necessary to understand the energy-use patterns of different categories of farmers in village ecosystems and the influence of income and family size on it. This paper reports such a study conducted in a village in Andhra Pradesh, India where dry land agriculture is
The household energy-use patterns observed in the village clearly showed that most energy is utilized for basic survival tasks such as cooking, cleaning, fetching fuel, water and other necessities of life. A number of measures have been suggested for enhancing the efficiency of energy use in rural household systems, which include the design and installation of a fuel-efficient improved chulha, with dampers, baffles and a grate in the combustion chamber, installation of family size biogas plants, planting of hardwood trees on field bunds, energy plantation on marginal and waste lands, utilization of solar. Ramachandra and Shruthi [68] have focused on the wind energy resources in Karnataka state in India. The study highlights the advantage of wind energy for application in rural and remote areas. It employs GIS to map the wind energy resources of Karnataka state and analyze their variability considering spatial and seasonal aspects. Maps of locations suitable for tapping wind energy have been prepared and a spatial database with wind velocities has been developed and used for evaluation of the theoretical potential through continuous monitoring and mapping of the wind resources. Agro-climatic zone wise analysis showed that the northern dry zone and the central dry zone were ideally suited for harvesting wind energy for regional economic development.

Kishore et al [45] highlight the role of biomass resources in developing countries for addressing global climate change concerns using India as a case study. This paper highlights the need to integrate the concerns of both developing countries and developed countries. The role of various biomass technologies for improving rural infrastructure and village power are discussed in detail. Municipal waste is a potential renewable energy resource according to Nilsson and Martensson [54]. The paper is based on a study of 12 municipal energy-plans that attempted to control and develop local energy-systems in southern Sweden. The results of the study showed that the resource energy planning follow the national energy-policies with respect to reduction of oil use, improved energy efficiency, and increased use of renewable energy. Rylatt et al [65] rates solar energy as the major resource and describes the development of a solar energy planning system, consisting of methodology and decision support software for planners and energy advisers. Intended primarily to predict and realize the potential of solar energy on an urban scale, the system will support decisions in relation to the key solar technologies: solar water heating, photovoltaic and passive solar gain. Based on a methodology for predicting the solar energy potential of domestic housing stock, it is implemented as a relational database application linked to a customized GIS. The methodology takes into
account the baseline energy consumption and projected energy saving benefits. To support this, the system incorporates a domestic energy model and addresses the major problem of data collection in two ways. The paper concludes with a discussion of possible planning scenarios to illustrate how the system may be deployed at various levels of granularity to assist targeting of individual properties or city neighborhoods, or for whole-city projections. The studies on resource energy planning models and their application at a decentralized level are limited. The models, which have been applied, are based on one of the available resources. The literature has focused on using just one or two available resources. Attempts at developing optimum energy mix of different resources which meet all the necessary needs of the rural people are limited. Artificial intelligence (AI) is a powerful tool for energy planning but still it is an emerging approach with little applications. Intelligent solutions, based on AI technologies to solve complicated practical problems in various sectors are becoming important. AI-based systems are being developed and deployed worldwide in myriad applications, mainly because of their symbolic reasoning, flexibility and explanation capabilities. Integrated energy planning based on decision support systems (DSS) approach is flexible, adaptable, and ecologically sound and gives an optimal mix of new renewable/conventional energy sources. A fuzzy based multi-objective analysis has been made by Agrawal and Singh [01] for the energy allocation for household cooking in Uttar Pradesh, India. The results focus on the economic, environmental and technical concerns as the main objectives included in the model. Decision-making in energy sector at decentralized level was attempted using LP models by Samouilidis and Ladia [77]. The authors have made an attempt to match the real decision structure of a given energy system, by decomposing a LP energy model into smaller models, with the corresponding system decision centers, applying the ‘transfer price’ algorithm of Dantzing and Wolfe [16]. The ‘master’ problem corresponds to the central planning unit, whereas the sub problems correspond to peripheral operating units, i.e. enterprises, usually state owned, which produce and distribute the energy carriers. The optimal plans of the peripheral units are submitted to the central unit, which through the mechanism of pricing of common resources, inputs and energy services outputs, coordinates the overall planning of the energy system. An illustrative example is given referring to the Hellenic national energy system.
Beccali et al [07] show an application of the multi-criteria decision-making methodology used to assess an action plan for the diffusion of renewable energy technologies at regional scale. In this paper, a case study was carried out for the island of Sardinia in Italy. Multicriteria decision-making was applied in order to assess groups of actions focused on the implementation part. For this, three decision scenarios were considered. In the first scenario, high priority was assigned to the environmental effects of the examined actions. In the second scenario, economic and social aspects were emphasized; in the third scenario attention was focused on the saving strategies and the rationalization of the energy production system. MOFLP problems were presented by Borges and Antunes [10]. This approach was illustrated to tackle uncertainty and imprecision associated with the coefficients of an input-output energy-economy planning model, aimed at providing decision support to decision makers in the study of the interactions between the energy system and the economy at a local and national level. Techniques used have been illustrated in a multiple objective input output model, supplied with actual data for Portugal, aimed at studying the interactions between the energy sector and the economy on a national level. Pokharel and Chandrashekar [59] have applied a suitable multi-objective programming method for rural energy analysis. Multi-objective methods provide decision makers with an opportunity to negotiate and explore different energy options. As an illustration of the proposed method, authors have analyzed the energy situation of a rural area and examined the trade off between energy supply, investment for energy programs, and employment generation.

Application of models for matching the projected electrical energy demand with a mix of energy sources at centralized level is limited. The literature mainly focuses in general either on only renewables or commercial sources at village or district level and not at national level. The energy-environment technology packages are rarely used at local, block and district level energy planning. Thus, it is necessary to develop criteria and identify environmental factors that need to be incorporated during integrated energy planning. The literature review in this project highlights the need to develop an approach and methodology to incorporate all the relevant environmental factors in integrated energy planning. It can be said that in developing countries like India, central energy planning models must be explored for an optimal mix to match the demand and supply. Thus, development of proper model and its application at centralized level is necessary.
In national level energy planning, the models and approaches need to be developed and made use of. The literature review reveals that the discussions for achieving 3-E goals and electricity model for minimizing generation cost by using optimum mix of resources which includes allocation of conventional as well as renewable energy sources has not been studied by others till date. This work has been developed in this project.