Region-wise Development of Integrated Renewable Energy System

THESIS

Submitted in partial fulfilment
of the requirements for the degree of
DOCTOR OF PHILOSOPHY

By
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Under the Supervision of
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CERTIFICATE

BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE
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This is to certify that the thesis entitled **"Region-wise Development of Integrated Renewable Energy System"** and submitted by **Sandip Shridharrao Deshmukh** ID No 2000PHXF411 for award of Ph.D. Degree of the Institute, embodies original work done by him under my supervision.

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[Sandip S. Deshmukh]

ABSTRACT

The gap in demand and supply of energy can be met by optimal allocation of energy resources and is need of the day for developing countries like India. 70% of India's population lives in villages and their main source of livelihood is agriculture. For the socio-economic development of India, energy allocation at the rural level is gaining importance these days. Integrated Renewable Energy System (IRES) in rural context aims at optimal resource allocation, thereby reducing dependence on commercial energy and reducing associated environmental hazards, and opening new avenues for employment generation.

Several authors have worked on energy planning at the micro level by taking into account population growth and agricultural operations. They have estimated the gap between the demand and supply of energy and made recommendations based on steps to be taken for closing this energy gap. However, there is a need to examine the locally available alternate energy sources along with traditional fuels for deciding on optimal mix of two. Proper utilization of renewable energy sources through IRES for meeting energy need is need of the day. The present work considers various energy resources (both renewable and non-renewable) available for meeting the demand for end use energy service.

The thesis aims at finding optimal energy resource allocation in the energy planning process. The energy needs vary from region to region. The energy needs of the region are used to define a region. The objectives of energy plan are related to socio-economic development of the region. The ultimate objective of energy plan preparation is thus to develop strategy for meeting present as well as future energy needs.

To demonstrate the development of IRES, a survey was conducted in villages of Jhunjhunu district of Rajasthan for estimating the end-use energy requirements and energy resource availability. The Goal Programming model has been developed by considering ten objective functions for energy resource allocation. The developed model is used for determining energy resource allocation for meeting present energy needs. Objective functions are grouped and six different scenarios are developed by considering alternative priorities to ten objective functions. The developed scenarios are evaluated on the basis of associated cost and emissions. On the basis, optimal scenario wherein cost and employment generation objective assigned a higher priority than other objective functions, is suggested for implementation.

To identify region for fast track development of IRES, an inter village-mix is considered in the surveyed villages. It is found that mix of two villages result in better realization of energy planning in the surveyed region. Energy allocation scenarios are generated for the defined region keeping in view of short and medium term objectives. The developed short and medium term scenarios are compared and optimal scenario suggested for implementation. The optimal scenario suggests that biomass, biogas and solar thermal is to be promoted for cooking, and solar thermal for heating end-use, LPG for cooking, and biomass electricity for lighting, pumping, cooling, and appliance end-uses is to be promoted.

To implement IRES, system sizing study was carried out using Hybrid Optimization Model for Electric Renewable (HOMER) for meeting estimated energy requirement in the year 2010-11 and different scenarios are developed to estimate the required size of system to be implemented. It is found that dual fired generator (biomass gasifier and diesel) of 500 kW capacity is to be selected for implementation.

The present work demonstrates new approach in micro level energy planning, for successful realization of renewable energy based projects.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol/Abbreviation	Description
η	Efficiency of End-use Utilization of Energy
d_j^-	Underachievement of Goal
d_j^+	Overachievement of Goal
b_j	Goal Value for The Objective, j
C	Unit Cost of Energy at End-use Point
CO_x	Carbon Oxides Emissions
e	Employment Generation Factor
FATE2-P	Financial Analysis Tool for Electric Energy Projects
HOMER	Hybrid Optimization Model for Electric Renewable
i	The End-use Resource Combination
IREP	Integrated Renewable Energy Programme
IRES	Integrated Renewable Energy System
L_j	Worst Possible Value For Objective, j
LOLR	Loss of Load Risk
MADM	Multi Attribute Decision Making
MARKAL	Market Allocation
MCDM	Multi Criteria Decision Making
MNES	Ministry of Non-conventional Energy Sources

LIST OF SYMBOLS AND ABBREVIATIONS (Contd...)

Symbol/Abbreviation	Description
MODM	Multi Objective Decision Making
MPEEE	Mathematical Programming Energy-Economy-Environment
NO_x	Nitrogen Oxides Emissions
NREL	National Renewable Energy Laboratory
OREM	Optimal Renewable Energy Model
PCEC	Per Capita Energy Consumption
PV	Photovoltaic
QSB	Quantitative Systems for Business
R	Reliability of System
RAPSIM	Remote Area Power Supply Simulator
RET Screen	Renewable Energy Technology Screen
S	Social Acceptance of Energy System
SO_x	Sulphur Oxides Emissions
w	Weighing Factor
X	Quantum of Energy used at the End-use Point

1.1 BACKGROUND OF THE WORK

The local energy resource utilization is a response to the need, which has now become very pressing, to limit the dependence of the regions on the conventional power grid to improve security of energy supply (Standing Committee on Energy, 2003 and MNES, 05). Planning Commission, Government of India, launched the Integrated Rural Energy Programme (IREP) in the early 1980s with an objective to meet the basic energy needs of rural people by utilizing local available energy sources. In 1994, the programme was shifted to the Ministry of Non-conventional Energy Sources (MNES).

The existing approach for planning and implementing energy programmes is top-down and sectoral. Ministry and State Nodal Agencies (SNAs) are responsible for the development of different energy systems and programmes in rural areas. These SNAs prepare and implement their own plans and programmes. These programmes are implemented by adopting top-down approach, wherein targets are preset, e.g. pump-sets to be energized; villages to be electrified; hectares for afforestation; biogas plants to be installed; improved stoves to be promoted, etc. In this approach, the targets are under achieved due to lack of motivation, education and training of the personnel (Neudoerffer *et al.*, 2001). Moreover, the targets for the different rural energy programmes and options do not have any relationship with one another. Therefore, there is a need to develop a region dependent Integrated Renewable Energy System (IRES), which incorporates proper utilization of renewable energy to supplement conventional energy sources.

In developing countries, constant endeavor is to evaluate various investment alternatives for meeting increasing energy demand on the basis of techno-economic viability. As a result, a large number of models have been developed for energy planning.

However, these models are suitable for centralized energy supply system using mainly conventional sources. It has resulted in inequities, external debt and environmental degradation (Hiremath, 2006). In this system, the power supply to the region remains inadequate, erratic and unreliable due to increasing pressure from urban centres. As a result, development of economically productive activities in rural areas has been far slower than in the urban areas.

The role of centralized (macro) energy planning is questionable when it comes to addressing the variations in socio-economic and ecological factors of a region (Beccali *et al.*, 2003). Decentralized (micro) energy planning is in the interest of efficient utilization of resources. The regional planning mechanism takes into account various available resources and demands in a region.

Rural areas in developing countries essentially depend on traditional fuels for all their energy requirements, such as thermal and electricity requirements. Also, dual energy and environment crisis, i.e. a lack of sufficient energy sources on one hand and the exploitation of forests for fuel-wood creating ecological imbalances on the other hand are issues to be addressed (Shyam, 2002).

The main objective of energy planning is to develop an optimal plan for energy resource allocation to various applications over 5 to 20 years with the consideration of future energy requirement at minimum costs and environmental emissions, maximum employment generation, social acceptance, reliability and system efficiency, maximum use of local energy resources and minimum use of petroleum products.

Several authors have worked on energy planning at the micro (village) level by taking into account population growth and agricultural operations. They have estimated the gap between the demand and supply of energy and made recommendations based on steps to be taken for bridging this energy gap. Taking into account the wide gap between demand and supply there is a need to examine the locally available alternate energy sources along with traditional fuels for an optimal mix of the two.

India has a huge potential in renewable energy sources. Renewable energy has been used for generating electrical power, heat, mechanical energy, and in some cases energy for transportation (Forson *et al.*, 2004). However, the proper deployment of renewable energy source devices as a part of IRES for meeting energy need is brought under focus. The present work considers various energy resources (both renewable and non-renewable) available for meeting the demand for end use energy service.

In the present work, optimal energy resource allocation in the energy planning process is carried out. The objective of comprehensive energy plan is to achieve strategy i.e. implementation of plan so as to cater to energy needs for present as well as future. The energy resource availability as well as energy needs vary from region to region. The existing energy resource and energy needs can be used to define a region. The energy plan or energy scenario is required to fulfill the objective of meeting energy requirements subject to certain limit or constraints. These constraints correspond to resource availability, technology options, cost of utilization, environmental impact, socio-economic impact, employment generation, at present as well as in future. The objectives of energy plan are related to socio-economic development of the region. The future instant, as a matter of choice, can be chosen at will. However, for energy development scenario, it is usual to choose future instant as 5 to 10 years distant.

In developing energy scenarios, range of supply and demand options is encountered. The supply and demand options define the decision making process. At each step of the decision making process, the energy planner is required to evaluate range of plans for implementation and need to propose options subject to fulfillment of objectives set for the energy planning process. A set of criteria is adopted for evaluation of proposed plans for achieving the objectives. The set of criteria to be chosen pertain to existing or future requirement of a given region. Thus, the energy planner is required to evaluate region wise pattern of proposed energy scenarios.

For the volume of data required for such an exercise, the use of computer models is necessary (Xiaohua and Zhenmin, 2005). Large volume of data is required to be handled on account of ranges of parameters to be considered. The ranges of parameters can be chosen to be set on the basis of the published data or data collected through field surveys. Published data is available only for few regions. For the region, where published data is not available, the data is collected through field surveys. The data collected can be used for preparing present as well as future energy plan for the region.

In the recent past, several researchers have developed computer models for achieving single objective optimization and multiple objective optimization. These models are reviewed and the usefulness of each of the model is evaluated in terms of results reported by researchers. The implementation of scenario within the range of accuracy permitted by the optimization models is also investigated.

1.2 OBJECTIVES OF THE STUDY

In view of above, the main objectives of the research work are:

i. to develop strategy for implementation of fast track IRES development plan for a rural region in northern parts of Rajasthan,

ii. to evolve an appropriate definition of region, for energy planning on the basis of scope for maximizing utilization of available renewable energy sources at micro level in the region,

iii. to develop an appropriate energy plan for achieving techno-economic and socio-economic objectives using IRES in the region,

iv. to evolve appropriate decision making process for the prioritizing scenarios for implementation in the region,

v. to size appropriate renewable energy system for implementation of prioritized scenario as an IRES for the region, and

vi. to identify barriers in implementing IRES and to recommend strategies for overcoming the barriers in the region.

1.3 METHODOLOGY ADOPTED FOR THE STUDY

The methodology adopted for the research work is shown in Figure 1.1. As shown in the Figure 1.1, following study tasks were completed to achieve the objectives of the study.

Phase 1: Survey was conducted in the identified villages of Jhunjhunu district in northern parts of Rajasthan, to estimate the energy requirement for different end-uses such as cooking, pumping, heating, cooling, lighting and appliances; and energy resource availability as shown in Figure 1.1.

Phase 2: Energy resource allocation is carried out for the study village by using multi-objective optimization model, from the point of view of cost, efficiency, maximum use of local resources and minimum usage of petroleum products, employment generation, social acceptance of energy resource, technical reliability of energy system, and environmental emissions such as CO_x, NO_x, and SO_x, associated with the use of energy resource for the end uses. The energy demand for various end uses and technological consideration of energy sources for utilization, were employed as constraints for optimization. Alternative scenarios are developed by assigning priority to the objective functions. The developed scenarios are compared on the basis of associated cost and emissions. On the basis, optimal scenario is recommended for implementation.

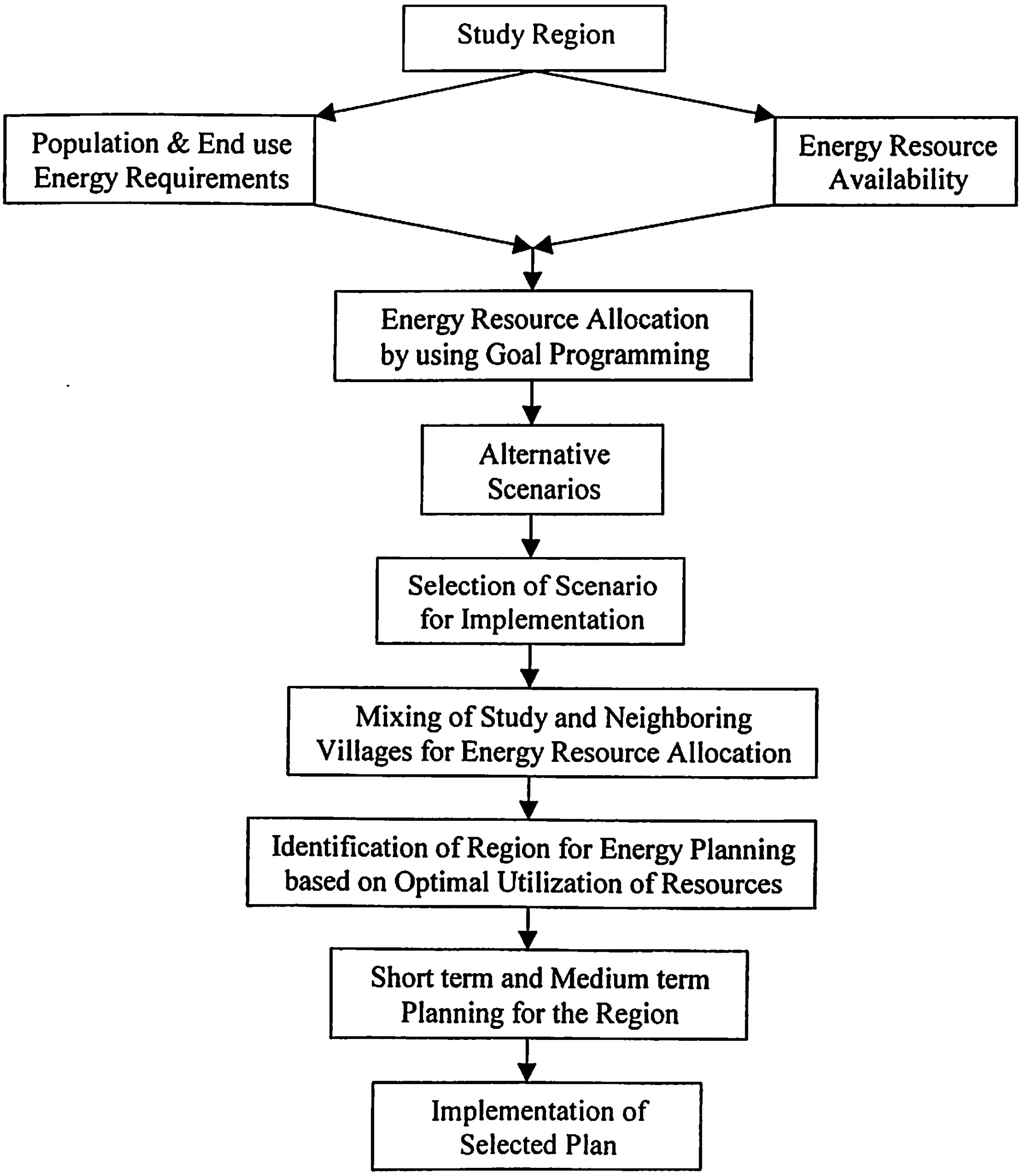

Figure 1.1 Methodology Adopted for the Present Work

Phase 3: As shown in Figure 1.1, the option of inter village-mix is considered to define region for energy planning. The region for energy planning is defined with respect to utilization of local energy resources.

Phase 4: For the newly defined region, energy resource allocation for present end-use energy requirements is carried out. For meeting short (over 5 years) and medium term (over 10 years) energy needs of the region, a range of energy scenario is generated considering energy availability and technological advances, for present and future. The developed scenarios are compared on the basis of associated cost and utilization of local energy resources. On the basis, optimal scenario is suggested for implementation.

Phase 5: In implementation of selected plan, designing of IRES for power generation to is carried out by using Hybrid Optimization Model for Electric Renewable (HOMER) software, developed by National Renewable Energy Laboratory, USA. Study of existing barriers in implementing IRES projects in the rural context is carried out and suitable measures to overcome the barriers is suggested.

1.4 SCOPE OF THE STUDY

The study is about development of power generation capacity region-wise, through renewable energy sources by considering optimal energy resource allocation at the micro-level from the energy planner's point of view. The objective of energy plan preparation is to develop strategy for meeting present as well as future energy needs. The energy resource as well as needs vary from region to region. These are used to define an appropriate region for micro level planning. The energy plan or energy scenario is required to fulfill the objective of meeting energy requirements subject to certain limit or constraints. The methodology adopted in the present study can also be applied to other regions, having range of available local energy resources and end-use-resource applications; new regions can be defined for micro-level energy planning.

1.5 ORGANIZATION OF THE THESIS

The research work is presented in seven chapters as follows:

Chapter – 1: In this chapter, rationale and structure of the thesis is presented. Need of decentralized energy planning for rural region is highlighted. The chapter also states the objectives of the research followed by the methodology adopted and organization of the thesis.

Chapter – 2: In this chapter, survey of literature on major issues involved in energy planning relevant to present research work is presented. The process of energy planning and classification of methods reported are discussed in detail. A review of literature on various issues in energy planning such as energy resource allocation, decision support system and system sizing is presented and research gaps are highlighted.

Chapter – 3: In this chapter, methodology adopted for estimating end-use energy requirement and energy resource availability in the region is described. The chapter highlights need of survey and importance of secondary and primary data in the survey. A detailed discussion on local parameters influencing energy use patterns of the region such as distribution of households, population distribution and landholdings, cropping patterns and irrigation intensity, and crop residues is presented.

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Chapter - 4 In this chapter, the methodology adopted for energy resource allocation to various end-uses to evolve an appropriate IRES for the surveyed villages of Jhunjhunu district of Rajasthan is described. The model development for energy resource allocation is described. The results of energy resource allocation to meet the present energy needs in *Panthadiya* village are presented. Six different scenarios are generated with alternative priorities of the objective functions. The results are used to select optimal scenario for implementation.

Chapter - 5 In this chapter, methodology adopted for identifying the region for IRES development among the surveyed villages of Jhunjhunu district of Rajasthan is discussed. The results of optimal energy resource allocation in neighbouring villages of Panthadiya village are presented. On the basis of optimal energy resource allocation, inter village-mix for the present energy needs to identify region for energy planning is carried out. For newly defined region, different energy allocation scenarios are generated for achieving short and medium term objectives of the region. These developed scenarios are compared and optimal scenario is recommended for implementation.

Chapter - 6 In this chapter, the implementation of recommended scenario is discussed. Method of sizing a system for electricity generation using HOMER software is presented. Different scenarios are generated for estimating the required size of system to be implemented. The barriers in implementing IRES plan at the regional level are identified. Appropriate mechanisms to overcome these barriers are recommended.

Chapter - 7 presents the summary of results, conclusions and recommendations of the study. Further scope of work and specific contributions of the study are also presented.

In this chapter, survey of literature on major issues involved in energy planning relevant to present research work is presented. The process of energy planning and classification of methods reported are discussed. A review of literature on various issues in energy planning such as energy resource allocation, decision support system and system sizing is presented, with a view to identify the trends in energy planning. Classification of multi criteria decision making methodologies reported till date is also presented. This is followed by survey of system sizing methodologies and tools used for sizing of energy system, corresponding to the prioritized scenario.

2.1 INTRODUCTION TO ENERGY PLANNING

Energy planning has been important always, though caught attention of planners only after the Oil-Crisis in the years of early 1970s. In post gulf-crisis time only, sufficient attention has been given to critical assessment of fuel reserves, rational use and conservation of energy resources, and long term energy planning. Energy planning process usually includes a study of sectoral demand and supply, forecasts of the trends based on economics and technological models, and a list of actions to achieve the objectives of the energy plan. The action plan is addressed to specific strategies and interventions, which are able to match demand and supply in the best possible way, considering associated constraints and factors. The constraints chosen in energy planning process are mainly cost and efficiency of the system. The energy planning also takes into account factors like political, social and environmental considerations, and is carried out taking into account the historical data collected in the previous energy plans of the country or region under examination (Byrne *et al.,* 1998; Sun, 2001). The concept of energy planning process can be as shown in Figure 2.1.

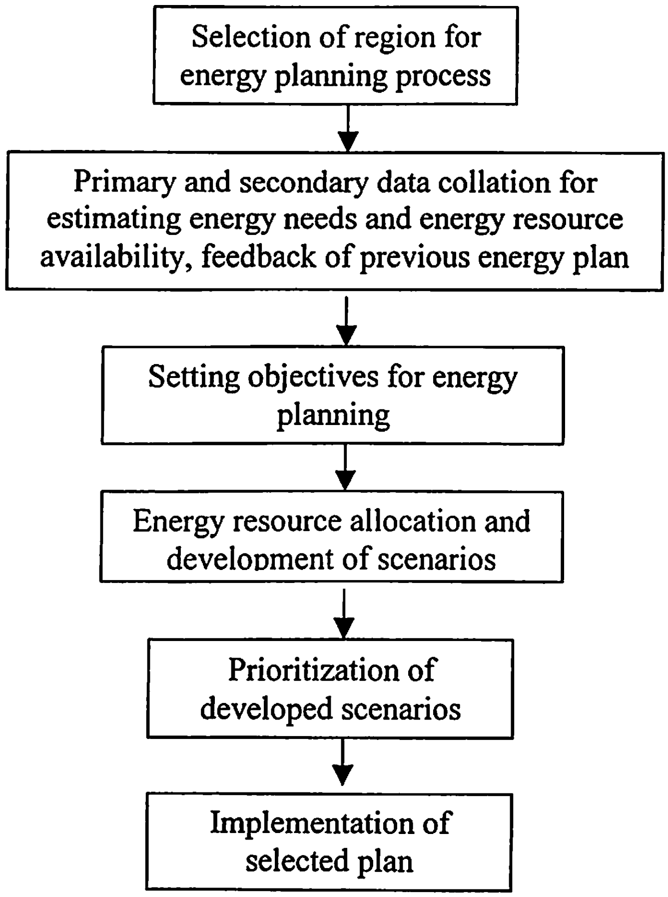

Figure 2.1 Energy Planning Process

Energy planning methods are broadly classified into three categories: (i) planning by models, (ii) planning by analogy and (iii) planning by inquiry. The accuracy of these methods depend on the intended time interval for implementation of energy plan, viz., short-term and medium-term, up to 10 and 20 years, long-term beyond 20 years. (Kleinpeter, 1995)

The energy planning by models methodology includes the optimization and econometric models. The optimization model is the most widely used tool for energy planning. Optimization models yield the optimal solution depending on a goal or objectives set in the energy planning process. The optimization model achieves optimization through minimization or maximization of the goal parameters. The optimization is carried out by using single or multi objective linear programming technique (Cormio *et al.,* 2003).

The econometric model uses mathematical and statistical methods such as regression analysis, to model economic systems. In particular, econometric models aim at empirical validation of theoretical models and at computation of values of operational parameters for economic operation of the system (Sontag and Lange, 2003; Notton *et al.,* 1996; Notton *et al.,* 2001). All the econometric models use empirical statistical data. The econometric model can also be used for energy system modelling. Energy system modelling involves one or several energy forms, different energy sectors and energy uses.

The energy planning by analogy allows prediction of supply and demand of energy over a period of times (Hadley and Short, 2001). In developing countries, energy planning is carried out on the basis of future scenario referred to as reference scenario. In developed countries, energy planning is carried out on the basis of the knowledge of recorded trends of energy supply and demand, and energy source potential. The analogy approach is often used to check and compare results obtained by using energy planning models (Jebaraja and Iniyan, 2006)

The energy planning by inquiry includes statistical evaluation of the responses of a selected panel of experts, to questionnaires, in order to formulate an accurate action plan for the future. The questionnaire is designed to seek the opinion on developed scenarios in multi criteria context (Pohekar and Ramachandran, 2004).

2.2 CLASSIFICATION OF ENERGY PLANNING MODELS

Energy planning models are classified on the basis of methodology adopted, spatial coverage, sectoral coverage and temporal coverage. The energy planning model under each class is discussed in this section with an aim to identify approach for micro-level energy planning in developing countries like India.

2.2.1 Methodological Paradigm

Depending on impact of energy supply and demand on economic issues, the planning methodology approach can be classified as bottom–up or top–down. Bottom–up approach entails detailed consideration of the energy resources, technologies, and energy demand. The bottom–up approach with detailed consideration allows assessment of implications of policy options such as technology mix, fuel mix, logistics and emissions in the energy sector at local, regional and national levels. The bottom–up approach to energy planning is useful for energy sector in isolation without consideration of its linkage with other sectors of economy (Kydes *et al.*, 1995).

The approach has been adopted by several researchers for energy planning in developing countries. Most developing countries have multiple future investment options to choose from, that can significantly alter their long-term technology mix, fuel-mix and consumption pattern. Unlike developed countries, they are still to make most of their investment decisions before the growth of their economy approaches saturation. Their economy will continue to witness changes in almost all sectors over next several decades. In developing countries, the policy for privatization, prices, taxes, trade norms, other regulatory measures, and R& D investments will continue to have significant impact on the energy consumption patterns in different end use sectors, and technological advances in the long run. Hence, bottom-up modelling approach is useful for analyzing energy policies, and evaluation of short to medium-term improvement options in technologies, fuels and operational practices, for the developing countries.

The top–down approach to energy planning, allows consideration of all the sectors of national economy along with their cross linkages. In such cases, effect of energy plan on macroeconomic indicators such as GDP or GNP and national level emissions can be investigated. Top-down modelling approach is useful in the cases of developed countries wherein technological efficiencies and rate of capital investments have already reached close to saturation levels.

2.2.2 Spatial Coverage

The energy planning model can also be classified in terms of its spatial coverage. The coverage can be for local, national, and global regions. For environmental planning, the spatial coverage of model is usually global or national. For energy planning the spatial coverage can be local, regional and national. Local, regional and national models adopt bottom–up modelling approach while national and global models adopt top–down modelling approach (Pandey, 2002).

2.2.3 Sectoral Coverage

Based on the sectoral coverage, models can be classified as economy-wide, sectoral, and sub-sectoral models. Sectoral models address concerns within an economic sector such as energy, industry, transport, and agriculture. Sub-sector models are those models which are used in coal sector, power sector, petroleum sector, steel industry, or railways. However, the scope for sectoral and sub-sectoral models can be regional or national i.e. economy-wide. Most of these models follow bottom–up approach, since other sectors of economy are not considered. Most economy-wide models follow top–

down approach, and address policy concerns at national or global level (Dossani, 2004; Dyner and Larsen, 2001)

2.2.4 Temporal Coverage

Models can also be classified on the basis of time scale considered for plan implementation. Accordingly, on the basis of temporal coverage of planning, the models can be classified as short-term (up to 10 years), medium-term (up to 20 years), and long-term (beyond 20 years). The model addressing energy plan at local, regional and national level can be short-term, medium-term or long-term model. Short and medium-term model follow bottom–up modelling approach. Long-term models consider either bottom–up or top–down modelling approach. Very-long-term models (100 to 300 years) always adopt top–down modelling approach, as for global models assessing impacts of global green house gas emission and atmospheric chemistry.

In the light of above, the methodologies adopted for energy planning in developed and developing countries can be summarized as shown in Table 2.1. It can be seen that the bottom-up approach is suited for a micro-level planning, short and medium term planning in a developing country. Therefore, in the present study bottom-up energy planning approach is adopted for developing energy plans for local region. for short + medium term planning.

Table 2.1 Classification of Energy Planning Approaches

Energy planning approaches		**Top-down approach suitable for**	**Bottom-up approach suitable for**
1. *Spatial*	a. *Local*	Developed countries	Developing countries
	b. *National or Global*	Developed as well as developing countries	Developing countries
2. *Sectoral*	a. *Economic sectors*	Developed countries	Developing countries
	b. *National economy*	Developed as well as developing countries	Developing countries
3. *Temporal*	a. *Short and medium term*	Developed countries	Developing countries
	b. *Long term*	Developed as well as developing countries	Developing countries
	c. *Very long term*	Developed as well as developed countries	---

2.3 RENEWABLE ENERGY PLANNING METHODS

Review of renewable energy planning models is presented in this section with an aim to identify energy planning methodology, objectives and constraints considered for macro and micro-level planning.

Several researchers have reported use of computer based optimization and simulation models in renewable energy planning. Also, number of optimization and simulation models have been developed for renewable energy allocation at both the macro (national level) and micro (local level) level of energy planning.

2.3.1 Macro-level Energy Planning

Mezher *et al.* (1998) has developed macro level energy planning model for energy resource allocation. The energy resource allocation has been carried out by multi objective goal programming technique for Lebanon from two points of view: economy and environment. The economic objectives considered were costs, efficiency, energy conservation, and employment generation. The environmental objectives considered were environmental friendliness factors. The objective functions were expressed as mathematical expressions and multi objective allocation was carried out using pre emptive goal programming technique. The constraints used in the optimization were total energy demand for various end uses such as cooking, pumping, lighting, hot water, home appliances, limit for use of solar energy for cooking, resource availability for biogas and hydro electric power. Alternative scenarios were developed for national level energy resource allocation for Lebanon, as follows:

- For promoting specific energy uses, viz., natural gas is promoted for cooking and for home heating, thermal power generation for water pumping and for appliances, hydroelectric power for lighting and for appliances and fuel wood for hot water.
- For an economic operation, by way of minimization of cost, maximization of efficiency and maximization of employment generation.
- For safety and security of energy supplies, by way of minimization of imported petroleum products and maximization of locally available resources.
- For environmental considerations, by way of minimization of CO_2, SO_x and NO_x emissions

The author argued that the proposed method allows decision makers to encourage or discourage use of specific energy resource for various household end uses. Later the authors demonstrated the use of fuzzy programming approach for energy resources allocation (Chedid *et al.,* 1999). The similar fuzzy multi objective approach for energy allocation for cooking in UP households (India) was also demonstrated by Agrawal and Singh (2001).

Suganthi and Samuel (1999) presented a macro level energy forecasting model for energy, economy, and environment considerations. Their model was based on two stage least square principle to calculate the future energy requirement. The requirement calculated was then used in the MPEEE (Mathematical Programming Energy-Economy-Environment) model developed by the authors. The developed model seeks to maximize the GNP-energy ratio subjected to the constraints such as limits imposed on the emissions of CO_2, SO_2, NO_2, total suspended particles, CO and volatile organic compounds. The authors concluded that the GNP-energy ratio is closely related to energy efficiency.

Iniyan and Sumathy (2000) presented top-down approach based optimal renewable energy model (OREM) to minimize the cost/efficiency ratio. Their model is represented in Figure 2.2. The potential of renewable energy sources, energy demand, reliability of energy system, and social acceptance of energy sources were considered as constraints for optimization. The results of optimization show that the renewable energy contribution is estimated to be around 8.13×10^{15} kJ, which will be about 25% of the total energy demand of India in the year 2020-21. The results of optimization also provides pattern of renewable energy utilization for 2020–21 in India. The sensitivity analysis was also performed by varying the potential of renewable energy sources. They have shown that the model is highly sensitive to variation in the potentials of renewable energy sources.

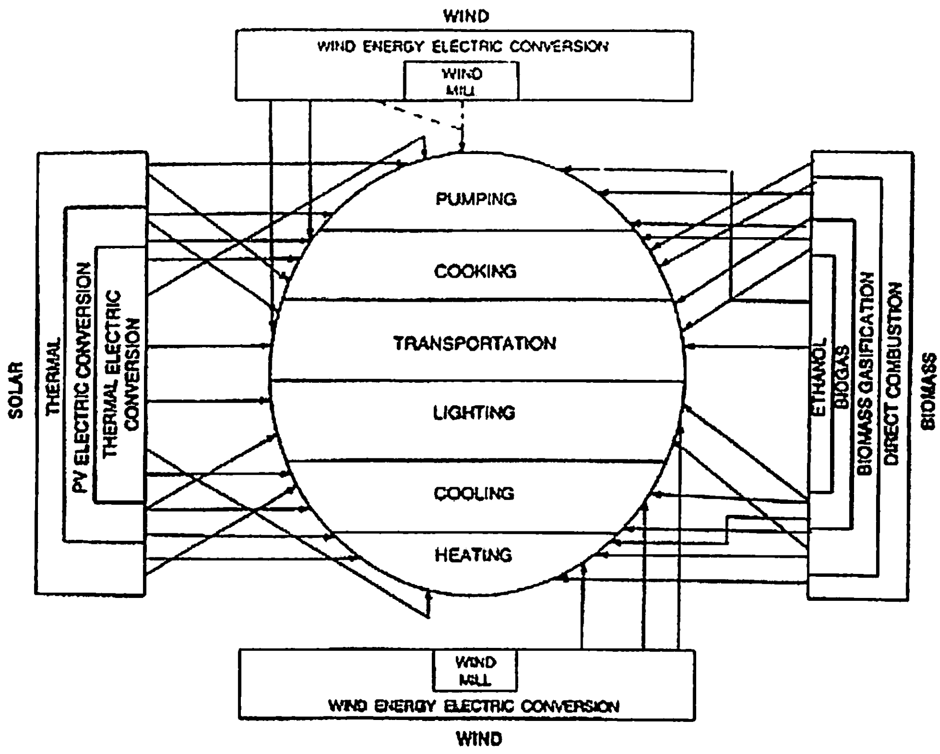

Figure 2.2 Schematic Representation of Optimal Renewable Energy Model Developed by Iniyan and Sumathy, 2000

The performance and reliability of wind energy system and its effects on OREM model has been presented by Iniyan *et al.* (1997). The demonstration wind farm of 4 MW, located at Muppandal region in Tamilnadu, has been considered for the study. The study was carried out in a wind farm consisting of 20 wind turbines of 200 kW capacity each. The average technical availability, real availability and capacity factor have been computed for the period 1991-95 and observed to be 94.1%, 76.4% and 25.5%, respectively. The authors have calculated reliability factor for the wind energy system and the reliability was found to be 0.5 at 10,000 hours of operation. Results of their analysis using OREM model show that the wind energy system can be used for pumping end use.

Suganthi and Williams (2000) adopted top-down approach for optimization model which minimizes the cost/efficiency ratio to determine the optimum allocation of renewable energy in various end uses for the year 2020-21 in India, taking into account growth in commercial and renewable energy requirement. The optimization model developed is shown in Figure 2.3. The results of their study show allocation of renewable energy resources to various end uses for meeting the renewable energy requirement during 2020-2021. For lighting, cooking, pumping, heating, cooling and transportation end uses, the renewable energy allocation is shown to be as follows: 1.26×10^{15}, 1.48×10^{15}, 1.71×10^{15}, 1.48×10^{15}, 1.01×10^{15} and 1.15×10^{15}kJ, respectively. The authors show that in 2020-21, the lighting energy requirement will be met by solar photovoltaics, the cooling and heating energy requirement will be met by solar direct thermal. In the case of pumping end use, 62% of the requirement will be contributed by solar photovoltaics and the remaining will be equally shared between wind and biogas. In the case of transportation end use, a major portion of the requirement will be met using biomass ethanol and biogas. The authors highlighted that during 2020-21, if the present consumption pattern persist, then each end-use requirement will be dominated by renewable energy source. The authors have carried out the sensitivity analysis. It was observed that due to 3% increase in social acceptance of bio energy resources, there was 65% decrease in solar photovoltaic utilization.

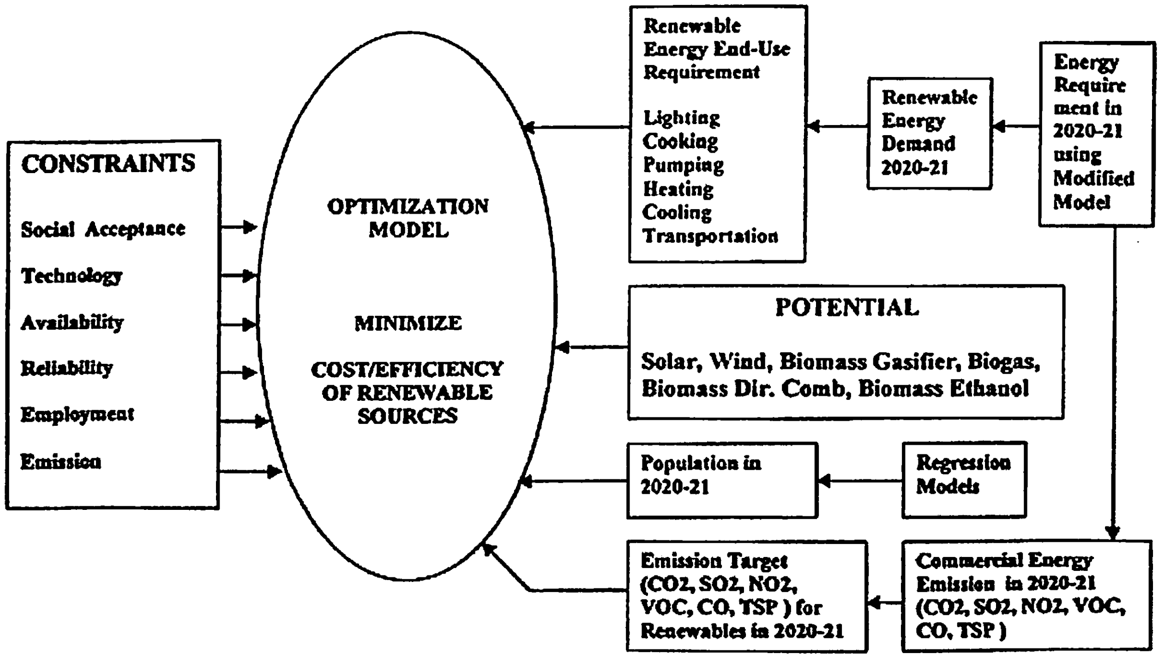

Figure 2.3 Schematic Representation of the Model Used by Suganthi and Williams, 2000

Similar exercise has been done for the years 2000-01, 2005-06, 2010-11, and 2015-16 by Suganthi and Williams (2000). In their study it was observed that the solar energy contribution in 2020-21 will be around 42% of total renewable energy requirement. The authors predicted that the biomass direct combustion and solar energy utilization will have an exponential growth in India over the years.

Ghosh *et al.* (2002) developed methodology by using bottom-up modeling approach. The approach takes into account the linkage between renewable energy and carbon emissions. The authors have assessed the potential for mitigation of CO_2 emissions in power sector. The mitigation potential was computed for the present power sector scenario by adopting renewable energy technologies to reduce the green house gas emissions and also estimated for the period of 35 years, from 2000 to 2035.

Mihalakakou *et al.* (2002) presented the scope for the utilization of renewable energy sources in the Greek islands of the South Aegean Sea area. The potential of renewable energy sources such as solar energy, wind energy, biomass, and geothermal energy, are investigated and analyzed. The authors have developed alternative scenarios such as (i) energy conservation scenarios and (ii) exploitation of renewable energy sources, for meeting the future energy demand. The energy conservation scenarios emphasize rational use of energy in all sectors of economy and promotion of combined heat and power systems. In renewable energy sources scenarios, maximizing use of renewable energy sources is considered.

Zouros *et al.* (2005) presented an integrated tool for the comparative assessment of alternative regulatory policies along with a methodology for decision-making, on the basis of evaluation of alternative scenarios for social welfare function. The social welfare function accounts for maximizing the benefits to market participants. The market participants considered were utility, independent power producers, regulators, and the consumers. The authors reported technical issues related to wind energy exploitation involving estimation of the secure wind power penetration, optimization of distribution network interface, and transmission expansion.

Mourelatos *et al.* (1998) examined the impact of CO_2 reduction strategy on the energy planning for Greece. The authors considered the conflicting economic and environmental goals which influence the penetration of renewable energy technologies. They have used linear programming technique to model energy system in Greece. They have optimized energy flows subject to the consideration of systems efficiency and system economics. Also, their model considered the constraints for CO_2 emissions from various energy generation and consumption processes. They have shown that the reduction of CO_2 emissions can be achieved through a large scale utilization of renewable energy sources into the existing energy system.

Several researchers have also studied potential of renewable energy technologies for penetration in existing power distribution network generation. Chedid *et al.* (1999) described a multi objective linear programming model in conjunction with fuzzy logic for the optimization of an existing electrical distribution network when upgraded by renewable energy technologies. The contribution of renewable energy to electric power generation was determined on the basis of existing capacity of distribution network and proper load management. They have determined optimal mix of renewable energy, which will be supplied to the existing grid, to fulfill the capacity of distribution network. They have reported that the optimization using fuzzy logic provides more flexibility to the decision makers in allocating energy resources.

2.3.2 Micro-level Energy Planning

Ramakumar *et al.* (1986) presented a micro level linear programming approach for the design of integrated renewable energy systems for developing countries. The energy resources, devices used to meet the end use energy requirement is shown in Table 2.2. The objectives of energy resource allocation were cost of energy and energy conversion efficiencies. The results were obtained subject to the constraint of energy demand and energy resource availability. Later the same authors modified their approach by considering prediction of energy resources for utilization (Ashenayi and Ramakumar, 1990; Ramakumar, 1992)

Table 2.2 List of Energy Resources, Devices, and End-use Energy Requirements considered by Ramakumar *et al.*, 1986

Energy resource	*Device used*	*Energy requirements*
1. ***Biomass-anaerobic fermentation-biogas***	Burner	Medium temperature heating, primarily for cooking
	Biogas fueled engine	Rotating shaft power for pumping and for small scale industries
	Heater	Low temperature heating for water and space heating
2. ***Solar radiation-PV array***	dc motor	Rotating shaft power for water pumping or for small scale industries
	Power conditioner	ac-electricity
	Controller	dc-electricity for battery charging
3. ***Wind energy-wind turbines***	Water pump	Rotating shaft power for water pumping
	Generator	Electrical energy generator
4. ***Water head***	Hydraulic turbines (mini or micro)	Rotating shaft power
	Hydraulic turbines generator	Electrical energy generator
5. ***Solar thermal collectors***	Solar cookers	Medium temperature heating for cooking
	Heat exchangers	Low temperature water heating and space heating
	Heat engine	Electrical energy generator
	Engine driven generator	

Optimization models have been applied by researchers to Indian conditions, for modeling renewable energy systems. Sinha and Kandpal (1991a) had 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 different energy conversion routes. Similar exercise has been done for irrigation (Sinha and Kandpal, 1991b) and lighting (Sinha and Kandpal, 1991c). Minimizing cost was chosen as the objective in all cases.

Joshi *et al.* (1991) developed linear programming model for decentralized energy planning for three villages in Nepal. The authors have presented results on optimizing use of energy sources subject to constraints of energy conversion efficiency of different end-uses, resource availability, and the cost. The results of their study show that use of energy sources in different regions is strongly dependent on demographic and climatic parameters. The authors suggested that in hilly villages, hydropower could become the cheapest source of energy if technical options were provided, but until then more efficient use of wood is the viable solution. The results also indicate that biogas is the economical option, subject to availability of dung, in hill and mountain villages.

Ramanathan and Ganesh (1993) developed a multi objective goal programming model for energy resource allocation at the micro level for Madras city in India. The objective functions chosen for the energy resource allocation were minimization of cost, use of petroleum products, CO_x, NO_x and SO_x emissions, and maximization of system efficiency, use of locally available resources, and employment generation. Using pre emptive goal programming technique the optimal energy resource allocation was carried out. The end uses considered for the analysis were cooking, pumping, lighting, and appliances. They have considered constraints such as total energy demand for various end uses, limit for the use of solar energy for cooking and resource availability for biogas for the optimization. The authors have also calculated the opportunity cost of alternative combinations. The opportunity costs were calculated on the basis of deviation in the goal programming objective function when the alternative combinations were employed for the energy allocation. Later the same authors used Analytical Hierarchical Process (AHP) technique to allocate priorities to the objective functions (Ramanathan and Ganesh, 1995). The authors have considered the aggregate option of economists, environment analysts and local people to allocate priority to the objective functions.

Srinivasan and Balachandra (1993) presented micro-level, bottom approach based linear programming model for Bangalore North Taluk. The developed model considers the available energy sources for various end uses and devices. The end uses considered were domestic cooking, heating, and lighting; and agriculture pumping and transportation. The objective function chosen for the optimization was minimization of total annual cost of energy for various end uses through available devices. The authors have considered constraints such as supply of energy through available devices, energy demand, and limit for the usage of devices for the optimization. The authors have predicted energy demand on the basis of growth rates in energy demand in the past. The authors have reported the need for efficiency improvement and energy carrier substitution for micro level energy planning. They have also emphasized the need to motivate and involve local people for surmounting the barriers in promoting use of renewable energy sources.

Rozakis *et al.* (1997) examined the combinations of energy resources for electricity generation at the local level in case of an isolated area of Greece. They have used computer model 'F-Cast' for simulating the operation of an integrated system. The integrated system considered consists of energy sources such as wind, micro-hydro, biomass, and conventional power generation. Their model determines the economic operation of integrated renewable energy power system on an hourly basis. The authors suggested that the model can be used to determine optimal combination of renewable energy sources for economic viability and to study its effect on socio-economic development of region.

Sarafidis *et al.* (1999) discussed a bottom up approach to match the supply of available renewable resources to the particular energy demand profile at the regional level. They have developed linear programming model for the energy resource allocation by considering efficiency of the renewable energy technology. The methodology was illustrated by a case study concerning two different Greek regions. They have considered various end use sectors such as residential, public, commercial, agriculture, transport and industry. The end use activities considered are space heating, water heating, cooking, refrigeration and air conditioning, indoor and out door lighting, thermal energy, machinery and electricity uses. They have estimated end use energy demand on the basis of space heating method for building sector, appliance saturation method for air conditioning and other electric uses in the residential sector, floor space method for electric uses, thermophysical law for estimation of energy demand for water heating and statistical records of energy data for fuels and electricity consumption in the industrial sector and for transport fuels. The space heating method includes thermal heat balance of dwellings, wherein the heat losses are calculated through the building shell and air infiltration. The appliance saturation method requires knowledge of saturation level, technical characteristics, and mode of usage for a given appliance. The floor space method includes building's cross sectional area and electricity needs are expressed on a per unit area basis. The thermophysical law includes per capita water consumption and comfort standards. The authors emphasized that in order to promote renewable energy sources, it is necessary to shift from a centralized to regional perspective, in energy planning sector.

Alves *et al.* (2000) presented the results of optimization of energy supply mix in Cape Verde Islands, Portugal. The potential of renewable energy technologies was assessed by considering social, economic and environmental aspects. For the purpose of optimization, the energy sector in Cape Verde Islands was characterized in terms of power generation capacity, distribution network, energy demand and supply, and renewable energy technologies such as solar, wind, geothermal and biomass.

Manolakos *et al.* (2001) developed a software tool for designing hybrid renewable energy systems. The hybrid system considered consists of a wind generator and photovoltaic modules, which are used for energy generation. The programme has been applied for simulating a hybrid system in order to meet the electricity and water needs of the Merssini village on Donoussa Island in the Aegean Sea of Greece. The simulation programme was used to optimize the design of hybrid energy system as well as to optimize the energy supply and storage. Cost and efficiency of the system was chosen as objective for optimization.

Devdas (2001a,b,c) presented an approach for renewable energy planning at the micro level in a Kanyakumari District of Tamilnadu, India and also identified the important parameters which control the economy of rural system, particularly in relation with energy inputs and outputs. The author has employed linear programming technique for optimum allocation of resources. The objective function of the linear programming model was to maximize the revenue of the rural system wherein optimum resource allocation is made subject to a number of energy and non-energy related relevant constraints such as cooking, lighting, energy cost, wood, biogas, natural gas, kerosene, electricity, transportation, animal power, human labor, operational holding and irrigation. The author also used regression analysis for forecasting future scenarios. The forecast was based on a set of projected inputs for the target year along with a projected set of technical coefficients. The advantages of scenarios analysis for micro level planning were discussed. The impact on scenarios were analyzing for (i) replacing field crop by plantation crop, (ii) introducing energy plantation, (iii) introducing fuel efficient stoves, (iv) increasing fertilizer price, (v) increased fertilizer application, (vi) increased population growth, (vii) drought conditions, (viii) decreased fuel wood availability, were developed. The developed scenarios were analyzed for recommending for energy resource generation and optimum usage of available energy resources.

Cormio *et al.* (2003) presented a bottom-up approach for formulating energy planning policies to promote use of renewable energy sources. A linear programming optimization methodology has been adopted to optimize energy system. The energy sources considered are biomass, solid waste, and process heat, and conventional power generation options. The optimization process, aimed at reducing environmental impact in most economical way. The result of optimization is the power generation plan which incorporates installation of combined cycle power plants, wind power, solid-waste and use of biomass for combined heat and power systems. The developed methodology is applied to case of the Apulia region in the Southern Italy. The results of the optimization reveals that the regional energy policy, aimed at satisfying the heat and energy demand by various end-use sectors through environment friendly technologies, can be supported mainly by combined cycle installations. The inclusion of additional cost of installation, associated with conventional power plant, in the objective function forces the conventional power plants option out of the energy planning, thereby increasing the scope for adoption of more efficient and environment friendly technologies, such as cogeneration and wind power.

Kai *et al.* (2004) evaluated potential of renewable energy resources to propose a regional energy system in Yakushima Island. The energy demand and supply options were specified, and the water potential was evaluated to develop new regional energy system. Their study reveals that the hydroelectric power yield on the island is sufficient to meet all the energy demands. The authors emphasized that the fossil fuel energy in Yakushima can be substituted with hydroelectric energy without causing an impact on the environment.

Weisser (2004) evaluated the costs of renewable electricity under various scenarios. The scenarios considered for the study were (i) business as usual, based on the power generation capacity expansion plan, (ii) hybrid, based on the assumption that the installed capacity of conventional power generation will remain at the same level, and to meet estimated future electricity demand co-fired biomass/waste combustion burners will be used, and (iii) renewable energy technology, based on the incorporation of renewable energy technologies in the existing electric power systems in Rodrigues, Mauritius. For each scenario cost of electricity was computed by discounted cash flow method. The net present value and the levelized cost of electricity over a period of 15 years were compared for conventional and renewable energy supply options. Also, they have carried out sensitivity analyses of scenarios with respect to political, economic and regulatory framework.

2.4 RENEWABLE ENERGY PLANNING MODELS

There are various models available to assess economic and environmental benefits of different supply and demand options in energy planning, both at the macro and micro level. The most widely used energy planning models are classified in the Table 2.3.

Table 2.3 Recommended Paradigms for Addressing Issues in Energy Planning

Paradigm	*Issues addressed in energy planning*	*Spatial coverage*	*Sectoral coverage*	*Temporal coverage*	*Examples*
Top-down simulation	*Impact of market measures and trade policies on cost to economies and global/national emissions* *Impact of market structure, competition and uncertainties on capacity investment, technology-mix, cost to consumers and emissions*	Global, national	Macro-economy/ Energy	Long-term	Integrated assessment e.g. AIM (Morita *et al.*, 1993) and general equilibrium models e.g. SGM (Shukla 1997), input-output modes and system dynamics models e.g. FOSSIL 2 (Naill, 1992)
Bottom-up optimization/ Accounting	*Impact of market measures and other policies such as regulations on technology-mix, fuel-mix, emissions and cost to energy systems; capacity investment planning*	National, regional	Energy	Long-term	Optimization e.g. MARKAL (Mathur, 2004), PERSEUS and accounting e.g. LEAP(Vashishta, 2004, Dhakal, 2003, Islas *et al.*, 2003, Tanatvanit *et al.*, 2003) models
Bottom-up optimization/ Accounting	*Impact of sectoral policies on sectoral technology-mix, fuel-mix, cost and emissions; planning for generation mix; unit scheduling; logistics*	National, regional, local	Energy	Medium-term, short-term	End use sector modes e.g. AIM/End-use (Morita *et al.*, 1996; Kainuma *et al.*, 1999), power sector, coal sector models

Cosmi *et al.* (2003) evaluated the feasibility of use of renewable energy sources on local scale, as per the European Union energy policies, which foster their utilization in member states. The authors presented an application of the R-MARKAL model to investigate the feasibility of renewable energy use for electricity and thermal energy generation. Their modelling approach was based on relationships and feedback between energy conversion and demand sectors such as residential, services and commercial, while taking into account legal issues and physical limits of the system. The model's solutions represent the minimum cost option and the results show that even in absence of exogenous environmental constraints, many renewable technologies are profitable and their investment costs are paid off in a medium term by lower operating and maintenance expenditures.

Energy planning models are also used in the Indian context. Market Allocation, (MARKAL) model has been applied by Shukla (1996) to Indian renewable energy systems. Mitigation of greenhouse gas emission had been analyzed using two models, (i) a bottom-up energy systems optimization model, MARKAL, and (ii) a top down macro economic Second Generation Model, SGM. The author has used MARKAL to analyze the technologies, peak electricity demand, carbon taxes and different energy scenarios. Carbon taxes and emission permits were analyzed using SGM. Mathur (2004) presented the use of MARKAL for the energy-environment analysis of the Indian power sector. Several scenarios were developed such as (i) base case, by assuming unconstrained development in power generation capacity except for presence of upper limits for renewable energy technologies as per their potential, (ii) bound growth, by the form of technological innovations, (iii) learning technologies, in the form of past experience, and (iv) bound growth with learning technologies. The developed scenarios were analyzed by cost minimization and by CO_2 taxations. The author has highlighted the potential of reduction in CO_2 emissions in the developed scenarios.

The review presented above show that a micro-level planning model is suitable for energy planning within a region. It is found that renewable energy optimization models generally deal with maximizing output, income, utilization of energy resources, profit, demand, performance of energy system or energy production. In the case of minimization, overall cost, energy system cost or capital investment are to be considered. The constraints considered are limitation of technology, supply, demand, efficiency, resource availability or installed system capacity. In addition to above, in recent years, there are certain other factors, gaining importance in favour of large-scale utilization of renewable energy sources. For instance, there is a certain amount of emission from renewable energy utilization. Secondly, when it comes to large-scale utilization, the installation of renewable energy sources needs a workforce for construction and maintenance, etc.

Hence, bottom-up approach for developing multi-objective linear programming model is adopted considering the above parameters, critical for utilization of renewable energy sources in existing energy system.

2.5 RENEWABLE ENERGY DECISION MAKING METHODS

Review of renewable energy decision making methods is discussed in this section with aiming at identification of appropriate decision making methodology suitable for micro-level planning energy planning.

Multi Criteria Decision Making (MCDM) is a branch of operations research models which deal with decision making subject to decision criteria. The MCDM methods are classified into two categories: multi-objective decision making (MODM) approach and multi-attribute decision making (MADM) approach (Climaco, 1997; Triantaphyllou *et al.*, 1998). The MCDM techniques have been widely used in renewable energy planning for ranking of developed scenarios.

The common characteristics of MCDM problems are conflicting criteria, incommensurable units, and difficulties in design/selection of alternatives. The difference between MODM and MADM approaches is located in the decision space (Logan, 1990; Huang *et al.,* 1995). The decision space in the MODM approach is continuous and alternatives are not pre-determined, while in the MADM approach, the decision space is discrete, and each alternative can be evaluated using a combination of analytical tools. The decision problem in MODM is solved using multi-objective linear or nonlinear mathematical programming models in which several objective functions are considered and optimized, subject to a set of constraints. In MADM, each planning or design strategy is associated with a set of attributes whereby various planning or design strategies can be compared. MADM is preferred when the criteria are qualitative in nature and MODM is preferred when criteria can be quantified. MODM problems are defined and solved by several alternative optimization models, such as compromising programming (Tzeng *et al.,* 1992; Koundinya *et al.,* 1995; Logan, 1990; Huang *et al.,* 1995), constraint method, goal programming, and fuzzy multi-objective programming (Zhu and Chow, 1997). For MADM problems, the utility function method (Keeney and Raiffa, 1995), tradeoff analysis method (Gavanidou and Bakirtzis, 1992; Yehia *et al.,* 1995) and analytical hierarchy process method (Rahman and Frair, 1984; Saaty, 1980; Saaty and Kearns, 1985) can be used (Maricar, 2004).

Table 2.4 Methods used in Multi-criteria Decision Making Frameworks

Major class of method	Type of information required on values of decision makers	Relevant feature of the provided information	Example applications to energy and environmental policy analysis
Dominance	No explicit value judgements required.	Tradeoffs between measurable attributes such as total system costs versus emissions.	Initial screening of mitigation options for CO_x, SO_x, NOx, VOC, mercury, etc. Initial screening of adaptation options to a changed economic or physical environment. Development of negotiation strategies for emissions reduction targets for multiple pollutants.
Maximin and minimax	Value judgement concerning levels of risk particularly toward negative or "down-side" outcomes.	Pessimistic decision makers (extreme risk aversion).	Development of "no-regrets" mitigation options (hedging strategies) for multiple pollutants. Development of least risk adaptation strategies to a changed economic and physical environment.
Maximax	Value judgement concerning levels of risk particularly toward positive or "up-side" outcomes.	Optimistic decision makers (extreme risk seeking).	Screening of energy efficiency projects on the basis of reductions in the consumption of fossil fuels or other criteria such as expenditures to commercialization. Screening of energy supply projects on the basis of implementation costs.
Conjunctive or disjunctive	Value judgements on the importance of needs, and the requirements to satisfy those needs.	Definition of acceptable and/or unacceptable attributes of alternatives within the framework of a hierarchy of needs.	Disjunctive methods: identification of adaptation options to changed economic or physical environment. Conjunctive methods: identification of components of rules for emissions trading regimes or negotiation positions of stake-holders.

Major class of method	Type of information required on values of decision makers	Relevant feature of the provided information	Example applications to energy and environmental policy analysis
Lexicographic or elimination by aspect	Comparative value judgements on importance of attributes of alternatives and acceptability. Elimination requires judgements of only acceptability.	Ordinal ranking of alternatives	Development of energy efficiency R&D portfolios for high-risk technologies with uncertain outcomes where the majority of attributes are qualitative. Identification of adaptation strategies where cultural or social attributes predominate.
Weighting or scaling	**Comparative value judgements on importance of attributes or groups of attributes with weights assigned.**	**Cardinal ranking of alternatives.**	**Identification of electricity generation expansion options.** **Comparison of effectiveness of demand-side options with supply options.** **Development of energy supply R&D portfolios which include environmental and social attributes.**
Mathematical programming models which use various types of weights for the decision variables (objectives or goals)	**Value judgements on the importance of an over-all objective and the development of weights proportional to the relative value of unit changes in the value function.**	**Cardinal ranking of alternatives.**	**Energy and environmental policy evaluation and development on a national or regional basis.** **Analysis of tradeoffs between market valued and non-market valued attributes in development of energy system expansions.** **Development of emissions hedging and trading strategies.**

(Source: Greening and Bernow, 2004)

Table 2.4 classifies various types of methods that have been used in multi-criteria analysis based on the levels of information on the decision-making environment, and the relevant feature of that information. Further, Table 2.4 provides applications in the area of energy and environmental policy analysis particularly where the two might be coordinated. For all of the reported methods in the literature, the analysis begins with the selection of criteria or attributes upon which to base a decision among alternative strategies or policies. The set of attributes that are included for each of the alternatives under consideration should be complete and exhaustive, and restricted to only those with no conceptual overlap (Keeney and Raiffa, 1995). Since all options can not be identified for inclusion in a policy, particularly the attributes of those options, nor the attitudes of all the decision makers known, formulation of a decision-criteria list can be a difficult process. To successfully complete the formulation of a decision criteria list, participants in the process need to have sufficiently similar backgrounds and knowledge to reach a consensus on important attributes and the scale for ranking. Even with similarity of background characteristics, expression of values from such a group is highly changeable [illegible] subject to many different factors. In the light of above the methodologies adopted for decision making in energy-environment planning, it can be seen that the multi-objective and weighting or scaling approach are suited for a micro-level planning.

When there is need to trade-off against one or more competing objectives, MOLP is used and also referred to as goal programming (Celik, 2003). The goal programming method employs a minimum distance concept based on goals specified by the energy planner for each objective. Additionally unknown variables are defined which represent positive and negative deviations from goals, in order to make them as a linear programming problem.

Several researchers have used multi-objective or single objective linear programming as discussed in the previous section. Therefore, in the present study multi-objective and weighting approaches are adopted for developing prioritizing the energy plans in a local region.

2.6 RENEWABLE ENERGY SYSTEM SIZING METHODS

Review of renewable energy system sizing methods are presented in this section. This is followed by survey of software tools used for sizing the energy system, corresponding to the prioritized scenario is also discussed with the objective of identifying suitable tool for implementing micro-level energy plan.

2.6.1 Renewable Energy System Sizing Methods

The interest in building capacity for power generation using renewable energy sources is growing for several well known benefits associated with utilization of renewable energy sources. This has resulted in evolution of several methodologies for developing appropriate power generation system configuration, which will be economically acceptable. In particular, advances in wind/photovoltaic (PV) generation technologies have increased their use as wind-alone, PV-alone, and hybrid wind/PV system. Several design scenarios have been proposed to design hybrid renewable energy systems, wherein a combination of wind, solar and in some cases diesel generator have been used as a backup. These scenarios are evaluated on the basis of associated cost of energy generation, reliability of power supply, operation and maintenance associated with the system, integration with the grid, power quality, etc.

2.6.1.1 Photovoltaic Stand Alone System

The worldwide demand for solar electric power systems has grown steadily over the last 15 years. The need for reliable and low cost electric power in remote areas is the primary force driving the worldwide photovoltaic industry today for a large number of applications, such as lighting, water pumping in remote areas etc. Photovoltaic technology is simply the least cost option, when environment emissions are considered associated with commercial technologies (Takanobu *et al.,* 1999). Typical applications of PV in use today include stand alone power systems for remote residences, wherein diesel generators are used as backup units.

Valente and Almeida (1998) have studied applications of diesel generator for electric power in small villages in northern Brazil. For these villages hybrid photovoltaic diesel option has advantage over traditional diesel system as it reduces fuel consumption, operation and maintenance cost, while improving the quality of service. A techno-economic feasibility study of PV/diesel hybrid system demonstrates that this system can reduce generation cost and increase the reliability of energy supply. The authors have developed software to optimize the generation cost. The results, compared with conventional diesel system cost, generated by the use of software show that for village up to 100 families the PV/diesel option is more reliable and economical than diesel system. In the software model it was assumed that all of the energy used during a day time does not pass through the batteries and thereby does not suffer any loss related to charging or discharging cycle of the batteries. Any excess energy produced is then saved in the battery bank for later use. In hybrid system the power of diesel generators is increased by adding one more diesel generator, in order to simulate a backup unit to supply the required energy. The addition of diesel generator in the system was considered to maintain the reliability of supply to the acceptable level.

Battery size is important while designing the PV stand alone system. El-Hefnawi (1998) has reported that optimizing the PV area and storage battery can minimize the cost of the PV system. The author used FORTRAN program to size the experimental system, which consists of PV system, storage sub-system, and diesel generator. The program developed by authors can calculate the minimum number of storage days and minimum PV array area. Their design of hybrid system was on the basis of load demand, diesel generator size, PV array area, battery capacity, current and voltage determination, and PV module configuration. The authors have compared the standalone PV system and hybrid PV/diesel system and found that hybrid system is more economic than standalone system due to optimization of solar panel area size and battery capacity.

Shereshta and Goel (1998) also discussed the impact of panel size and battery capacity on indices of performance of standalone PV system by conducting study on the optimal sizing of standalone PV system. Their analysis was based on the simulation of solar radiation and load demand data. The model for solar radiation was developed on this basis of historical data collected. The model for refrigerator load, representing a single load in stand alone PV system was established from experimental measurement. Their simulation process can be broadly divided into three sections. The input combination to be investigated for the support data such as PV module, insolation, load demand, battery. After processing the input data, the results of simulation were obtained in the form of total cost, risk indices, loss of load hours, loss of load, energy not utilized or energy loss. The results of their analysis show that system with large array size and small battery size exhibits large amount of energy loss, and system with small array size and large battery size produce loss of load hours.

Although solar energy is environmentally benign and available in abundance, the stand alone photovoltaic system is an expensive option due to high cost of solar cells but these energy systems have good prospects and many opportunities in hot climates (Shaahid and Elhadidy, 2004; Valente and Almeida, 1998).

2.6.1.2 Wind Stand Alone System

The kinetic energy in the wind is a promising source of renewable energy with significant potential in many parts of the world. While designing a wind power system, it is crucial to understand existing electricity load profile and the available resources i.e. available wind speed and available wind turbine rating. The energy that can be captured by wind turbines is highly dependent on the local average wind speed. Regions that normally present the most attractive potential are located near coasts, inland areas with open terrain or on the edges of bodies of water. Some mountainous areas also have good potential. In spite of these geographic limitations for wind energy project location, there is ample terrain in most areas of the world to provide a significant portion of the local electricity needs with wind energy projects. The integration of wind turbine with diesel/battery hybrid system is becoming cost effective in windy location.

Nfaoui *et al.* (1996) focused on remote areas of Morocco, where diesel generators are used to provide electrical power. Such systems are often characterized by low efficiencies and higher maintenance costs. A wind/diesel energy system with battery storage has been modeled using the Tangiers's wind regime over a one year period (1989), and synthesize consumer load data base on the characteristics of typical usage of domestic appliances, along with the estimated working patterns of a local isolated community. The authors have used a more realistic hourly consumer load, which was the result of an experiment realized in a Moroccan village using a diesel engine to provide electricity for lighting and other appliances. The optimum wind turbine size and the benefit of storage system on fuel consumption were also reported. The benefits were calculated on the basis of optimal design of the system to meet the energy demand at minimal cost of energy over the lifetime of the equipment.

Elhadidy and Shaahid (1999) analyzed hourly mean wind speed data for the period 1986-1997 recorded at the solar radiations and meteorological monitoring station Dhahran ($26^0$32` N, $50^0$13` E), Saudi Arabia, to study the optimum size of battery storage capacity for hybrid wind/diesel energy system at Dhahran and the impact of variation of battery storage capacity on hybrid system. The monthly average speed for Dhahran ranges from 4.1 to 6.42 m/s, as a case study, the hybrid system considered in the analysis consist of two 10 kW wind turbine, together with a battery storage system and a diesel backup. The yearly and monthly average energy generated from the hybrid system have been presented. More importantly, the study explores the impact of variation of battery storage capacity on hybrid power generation. The results exhibits a trade off between size of the storage capacity and diesel power to be generated to meet the specific annual load distribution and for a given energy generation from wind turbines. The energy generated from the backup diesel generator and number of operational hour of the diesel system to meet the specific annual electrical energy demand has also been presented. The diesel backup system was operated at times when the power generated from wind turbines fails to meet the load and when the battery storage was depleted. Results show that for economic consideration, the optimum usage of storage and for optimum operation of a grid. The author has reported that optimum system would be able to supply 84.16% of annual electrical energy requirement of the site.

Habid *et al.* (1999) presented an optimization procedure for hybrid PV/wind energy system which can be used to satisfy the requirement of a given load distribution. Their analysis aimed at satisfying a constant demand of 5 kW in the city of Dhahran, Saudi Arabia. The optimization procedure aimed at calculating the optimal percentages of power produced by each of two separate systems that make up the hybrid system. The objective of the optimization procedure was to size a hybrid system that satisfies annual load demand with minimum cost. The authors investigated hybrid system with a PV array area of 392 m^2 and multiple wind turbines each with 18 kW rated power. The results of their study show that the optimal solar/wind ratio corresponding to minimum capital cost is 70%.

Al-Ashwal and Moghram (1997) introduced a method enabling the assessment of the optimal proportion of PV to wind generator capacities. The method is based on evaluation of cost and loss of load risk (LOLR). According to the daily electrical energy demand, the required generating system can be designed with different alternatives: only PV, only wind, and combined PV and wind generator in different proportions. For each of alternative combinations, the cost and LOLR is computed. Cost includes capital and maintenance costs of PV and wind generator. LOLR is the probability of failure of the generating system in meeting the daily electrical energy demand due to deficient energy source.

The combination of photovoltaic and wind with battery storage and diesel back up system is becoming a viable, cost effective approach for electrification in remote area.

Chedid and Rahman (1997) provided a deterministic analysis approach to determine the optimal design of a hybrid PV/wind system for either autonomous or grid linked applications. In their work, power system was a combination of solar, wind and battery sets. In the power system, depending on the application, either diesel generator or grid option are considered for backup purpose. The authors have used linear programming technique to minimize the average production cost of electricity while meeting the load requirement in reliable manner. The analysis was carried out for three modules, namely, preprocessor, optimization tool and control module. In the analysis for preprocessing, the authors have considered the load demand, solar and wind resources averaged over several years as well as technical data. The selection of system components were achieved through the optimization and then whole design was tested in control module through which the size of storage was determined. A controller which monitors the operation of the autonomous or grid linked system was also designed by the authors. The controller designed by the authors determines the energy available from each of the system components and associated environment benefits of the system and also provides details related to cost, unmet and spilled energy, and battery charged and discharged losses.

Chedid and Saliba (1996) developed a new formulation for optimizing the design of an autonomous wind-solar-diesel-battery energy system. Their formulation employs linear programming technique to minimize the average production cost of electricity, while meeting the load requirements in a reliable manner. The computer program was developed to consider the necessary input data and to optimize the system. To study the effect of parameters predefined by the system designer on the optimum design, several sensitivity analysis studies were also performed to investigate effect of the loss of load, the load level, the maximum available wind area, the maximum available solar area, and the diesel engines lifetime. The authors have designed a controller which monitors the operation of the autonomous system. The operation of the controller was based on two strategies; (i) energy available with battery storage should be used before the diesel engines, and (ii) the supply is made through diesel engines only. This was carried out to compare the performance of isolated diesel system and the hybrid renewable system. The proposed optimization and control technique was tested in Lebanon.

Yokoyama *et al.* (1994) proposed a deterministic approach to optimal unit sizing for hybrid system utilizing PV and wind energy, and to examine combination of devices which are most suitable. Their approach accounts for the effect of installation of a system on economics of power generation. The optimization problem is considered to be multi-objective and discrete set of Pareto optimal solution was derived by using weighting method. The annual total cost and annual energy consumption are selected as multiple objective function to be minimized from the viewpoint of economy and environment protection.

2.6.2 Renewable Energy Sizing Tools

Successful implementation of energy generation plan depends on the proper utilization of available energy sources, economic performance of energy system, and reliability of operation. In order to simulate these indicators different software packages exist with, a varying degree in user friendliness, validation of simulation models, accuracy of system models, and possible configurations to simulate (Turcotte *et al.*, 2001). Most of these software tools simulate the system performance based on the energy resource availability and technical parameters of the system. The hybrid combination consists of mix of one or more energy sources. The energy sources for hybrid combination are chosen on the basis of their availability in the region.

The software tool incorporates mathematical expression for governing the energy systems operation, desired energy flow and costing of the system configuration. These packages are valuable to assess hybrid system configuration suitable for a given case and enables study of effects of changing component size and energy flow. The software tools available can be classified on the basis of mathematical technique and purpose for usage as follows (Gulhane, 2002):

- Pre-feasibility tools,
- Sizing tools,
- Simulation tools, and
- Open architecture research tools.

2.6.2.1 Pre-feasibility Tools

A pre-feasibility tool automates the calculations and helps to determine whether a hybrid system makes sense for a specific application, both in terms of the energy source used and the life cycle cost of the system. These tools are usually aimed at approximate sizing but often have a comprehensive cost and financial analysis. Pre-feasibility tools are often implemented as spreadsheets, since they require only the automation of simple calculations, with minimum iteration work. More advanced pre-feasibility tools also include embedded macros or code to perform more detailed analyses. These tools are normally used by energy planners, consultants, and financiers to evaluate the economic feasibility of specific hybrid combination. Some of the available tools in this category are FATE2-P (Financial Analysis Tool for Electric Energy Projects), RET Screen (Renewable Energy Technology Screen).

2.6.2.2 Sizing Tools

The sizing tool are used to determine size of the system, given an energy requirement, it determines the optimal size of each of the different components of the system. Different tools optimize different objectives. Some tools minimize the life cycle cost of the system, while others determine system size depending on desired function of the system. Most sizing tools provide detailed information about energy flow through components during the critical periods of the year. Sizing tools are usually compact automized software packages. They generally have a user friendly interface designed for proper data entry. Some of the available tools in this category are Hybrid Designer, PVSYST.

2.6.2.3 Simulation Tools

In simulation tools, energy system designer must specify the nature and size of each component. The tool requires that, the energy system designer correctly identifies the key variables and then repeatedly run the simulation, adjusting the variable manually to converge on acceptable sizing. The tool then provides a detailed analysis of the behavior of the system over a chosen period, usually a year. The time resolution of the simulation (i.e. the length of the time step) varies from packages to packages and depends on the level of details required and the availability of input data (e.g. weather data). The results of simulation are usually obtained on hourly basis. The results can be used to verify system sizing, investigate the impact of future changes in the load and performance under typical conditions, e.g. worst weather. The sensitivity of the design to various parameters can also be investigated. The failure or deterioration of the components can also be investigated. Simulation can also provide information about the economic and environmental characteristic of the system, such as life cycle cost and associated CO_2 emissions.

For all these tools, energy system designer enters data related to system components, load demand, location, weather conditions, energy systems cost and energy resources, etc. The program then simulates the system and shows the power generated, consumption and storage as a function of time. Some tools such as PVSTAT and HYBRID 2 also provide detailed economic analysis of the system life cycle cost. Some of the available tools in this category are RAPSIM (Remote Area Power Supply Simulator), SOMES, HOMER (Hybrid Optimization Model for Electric Renewable) and Hybrid2.

2.6.2.4 Open Architecture Research Tools

High level of flexibility is desired to perform research and development at the component and system level in the interaction of the components. Optimization and simulation tools can perform extensive sensitivity analysis, they do not permit energy system designer to modify the algorithms that determine the behavior and interactions of the individual components. For this purpose, open architecture is required; the software consists of a selection of routines. After describing the components and platform for linking these routines together, the energy system designer is at liberty to add new routines. Such research tools can be either implemented within a commercially available, general purpose simulation environment or programmed and complied in a language such as FORTRAN, C or Pascal. The flexibility and power of open architecture tools make these tools useful for researcher; their concomitant complexity limits their usefulness for commercial system analysis, sizing and design. However, the results of open architecture tools can also be obtained by using sizing or simulation tools. The available tools in this category are MATLAB, SIMULINK, and PSPICE.

Several researchers have used system sizing tools to simulate the performance of energy system. McGowan *et al.* (1996) compared the performance results obtained using two computational models, namely Hybrid2 and SOMES for simulating the performance of hybrid power system. The results show that both models predict the technical and economic (life cycle cost) performance of hybrid power system that typically comprise of renewable energy sources, a battery bank, and a diesel generator. For the case study the authors have considered the application of hybrid system in a selected South American site located in Brazil. Actual system configuration was used as a basis for comparison of prediction from these models. The results of their analysis show that both the models provide similar performance results. The same approach is adopted by Milligan to compare and size the system using HOMER.

Lew *et al.* (1998) presented use of model to provide reliable source of rural electrification for household in Interior Mangolia. The hybrid PV/wind system, using batteries was designed using the tool HOMER developed at National Renewable Energy Laboratory (NREL). The authors used optimization tool HOMER and simulation tool Hybrid2. The optimization program HOMER was used to optimize the system configurations for a variety of household load sizes, from the average low demand to the average high demand. A 30% maximum depth of discharge in batteries was assumed in these HOMER runs, based upon specifications. Using the time step simulation model Hybrid2, the system configuration was fine tuned for the medium demand household with a load of 633 kWh/yr.

Review of renewable energy system sizing methods and survey of commercially available tools reveals that at the level of energy system designer, sizing simulation tools provide more flexibility and also provides detailed economic operation of the system. Therefore, for the present work HOMER system sizing tool is used.

2.7 RESEARCH GAPS IDENTIFIED

In formulating the energy policy, the issue of centralized or decentralized energy planning for a particular region, subject to set of economic and social priorities, is an essential policy concern. A complete framework for energy policy analysis for developing countries needs to include both centralized and decentralized planning options. The comparison of decentralized planning with the centralized planning can be made for comparison of geographical distribution of demand, economic implications of remoteness of location, dispersed availability of resources like biomass, specific requirements of decentralized technological systems like local maintenance support and locally sustainable supply of fuel, are important considerations. Many rural areas are witnessing transition from traditional to modern life-styles and this fact may become important for assessing long-term patterns of demand and supply for decentralized energy planning. In such a scenario, the energy planner has to shift the level of planning process from macro to micro-level.

In view of the literature survey, following main research gaps are identified.

- Although there is a considerable literature available on energy planning at the macro level, not many case studies are available for energy planning at micro level.

- There is need to reorient traditional approach to energy planning so as to promote utilization of local renewable energy resource.

- There is emerging need to formulate method for developing IRES for socio-economic development of rural regions.

The present research work aims at generating micro-level energy plans over short and medium term for rural region in northern parts of Rajasthan, which seeks to achieve increased utilization of local renewable energy sources.

Chapter 3: Energy Requirements and Energy Resource Estimations

This chapter explains the methodology adopted for calculating end-use energy requirement and energy resource estimation in the region. The chapter highlights need of survey and importance of secondary and primary data in the survey. A detailed discussion on major local influencing parameters on rural economy such as distribution of households, population distribution and landholdings, cropping patterns and irrigation intensity, and crop residues is presented. Estimated end-use energy requirements and energy resource availability of the surveyed villages is presented.

3.1 NEED OF SURVEY

Energy use patterns are closely linked to agro-climatic and socio-economic conditions. Energy problems in rural areas are also closely linked to soil fertility, landholding, livestock holding, etc. Energy planning of any region should be based on the existing levels of energy consumption. However, the information available in published form is either at the state level or at the national level. Devdas (2000a,b,c) highlighted that the regional developmental activities have to be based on detailed information from each sector. Hence, a detailed energy survey was conducted by visiting and consulting local people, to understand the household and agricultural energy use patterns in various socio-economic zones. For this purpose, survey was conducted to investigate household and agricultural energy consumption due to cooking, lighting, pumping, cooling, heating and appliances in the identified villages.

3.1.1 Methodology of Survey

Jhunjhunu district located in Northern part of Rajasthan, India, is one of the prosperous districts of Rajasthan with an area of 5929 sq. kms (latitude 28.06^0 N, longitude 75.20^0 E). Most of the part of the district is falling under semi-arid zone of desert (CAZRI, 2004). The main energy resources in Jhunjhunu district are traditional fuels, mainly fuel-wood, agricultural residue and dung. The households in rural areas of Jhunjhunu district possess their own land for cultivating Mustard and Wheat as the major crops, and are dependent on agricultural revenue.

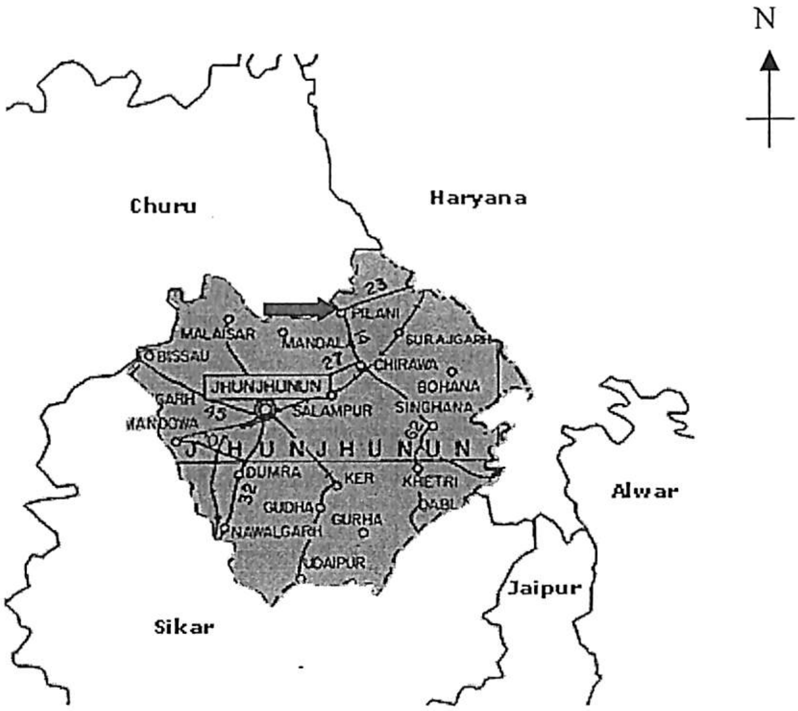

Figure 3.1 Map of Jhunjhunu District Rajasthan, India

Preliminary investigations were conducted in six villages of Jhunjhunu district for household and agricultural energy needs such as energy resource availability, accessibility, technological support and local cooperation / support by visiting the villages to choose the region for investigation. After the preliminary investigations *Panthadiya* village, a village in

Morva Panchayat, is identified as a study village for the design of integrated renewable energy system. The *Panthadiya* village is also considered to study intra-village energy resource allocation with the neighboring villages namely *Bisanpura 1st, Bisanpura 2nd, and Morva.*

The detailed energy survey was then conducted in *Panthadiya,* consisting mainly of secondary and primary data. The secondary data is collected from respective government offices and is used to prepare framework for the primary survey. The energy needs were estimated for various household and agricultural end-uses such as cooking, pumping, heating, cooling, lighting and appliances. During the initial survey period, it is observed that only 2 to 3 houses in the village are using pumps for pumping end-use. Therefore, the pumping end-use energy requirement for household is neglected for the present study.

3.1.2 Collection of Secondary Data from Government Agencies

Most of the secondary data such as landholding, demography, and livestock population, was collected form government offices. Landholding particulars for each household were collected from Village Accountants' offices (*Patwari*). Data on village wise demography and occupational and infrastructural facilities was collected from the *Tahsildar's* office at *Chirawa.* Data on livestock population was collected from the veterinary departments of the sub-tahsil at *Surajgadh* and tahsil at *Chirawa.* Table 3.1 show information related to demography and livestock of the surveyed villages.

Table 3.1 Demographic Information and Livestock Population of Surveyed Villages

Name of the Village	*Population*	*Total Land (in hectares)*	*Irrigated Land (in hectares)*	*Number of Cows*	*Number of buffalos*	*Number of Camels*
Panthadiya	1483	522	481	366	340	36
Bisanpura 1st	647	190	169	239	111	11
Bisanpura 2nd	717	185	167	112	242	20
Morva	2477	857	733	341	672	60

(Source: Census, 2001)

The secondary data available with government offices is compiled over a period of several years by the concerned officials. Furthermore, data regarding several aspects having an important bearing on rural energy planning are not readily available in the published statistics. Hence, survey was conducted for the household energy needs using multi-stage schedules for the present investigation. The secondary data was analyzed to select households by stratified sampling, based on landholdings and community, for the energy survey. This survey was conducted during December 2004 to October 2005, which is considered to be the base year for this study (2004-05).

Table 3.2 shows the variation in secondary and primary data for number of households in the surveyed villages. The variation in the data is attributed to methodology adopted for estimating number of households. The secondary data for number of households as reported in the Census, 2001 is calculated on the basis of landholdings as per the government records. It is observed that, in most of the families, operational landholdings records available in government offices are not updated. Therefore, primary data on actual number of households is estimated by consulting *Sarpanch* and senior citizens of respective villages. The estimated primary data on number of households is then used to conduct the survey.

Table 3.2 Variation in Secondary and Primary Data for Number of Households

Name of the Village	*Number of households as reported in Census 2001*	*Number of households estimated after survey*
Panthadiya	182	240
Bisanpura 1st	95	101
Bisanpura 2nd	86	135
Morva	327	355

Table 3.3 show the population of the villages as reported in Census 1991 and Census 2001. The recorded population growth rate for a decade is 0.29, 0.21, 0.07, and 0.19 for *Panthadiya, Bisanpura 1st*, *Bisanpura 2nd*, and *Morva* village, respectively.

Table 3.3 Population of Surveyed Villages

Name of the Village	*Population as reported in Census 1991*	*Population as reported in Census 2001*
Panthadiya	1154	1483
Bisanpura 1st	538	647
Bisanpura 2nd	670	717
Morva	2088	2477

It is observed that the population increases exponentially (Population Reference Bureau, 2005). In order to estimate the population of villages in the basis year i.e. 2004-05 for energy resource allocation, exponential regression analysis for the population in the year

1991 and 2001 is performed. Exponential regression analyses resulted in correlations and are shown in Figure 3.2.

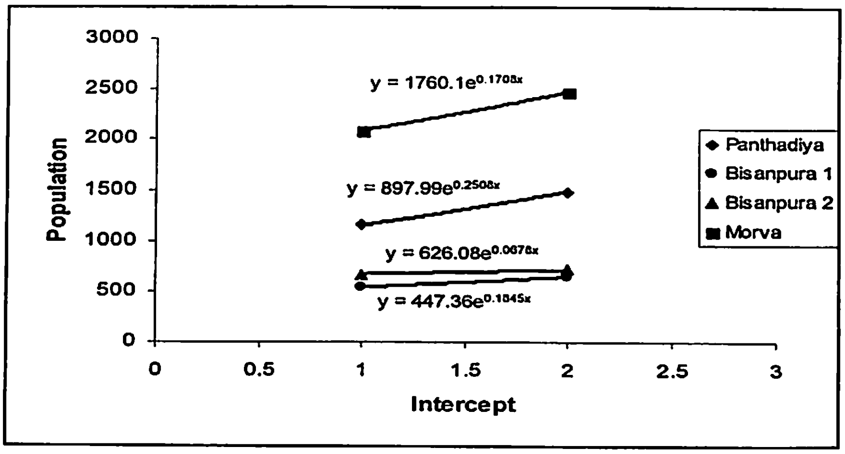

Figure 3.2 Results of Exponential Regression Analysis for Surveyed Villages

The exponential growth observed in last decade i.e. 1991-2001 is used as a basis for estimating present (i.e. 2005) and future (i.e. 2010 and 2015) populations of surveyed villages.

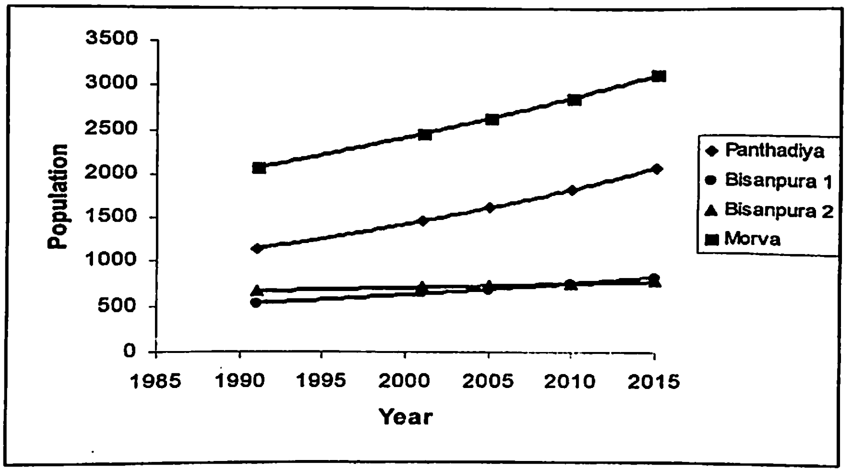

Figure 3.3 Estimated Populations of Surveyed Villages using Exponential Regression Analysis

1991 and 2001 is performed. Exponential regression analyses resulted in correlations and are shown in Figure 3.2.

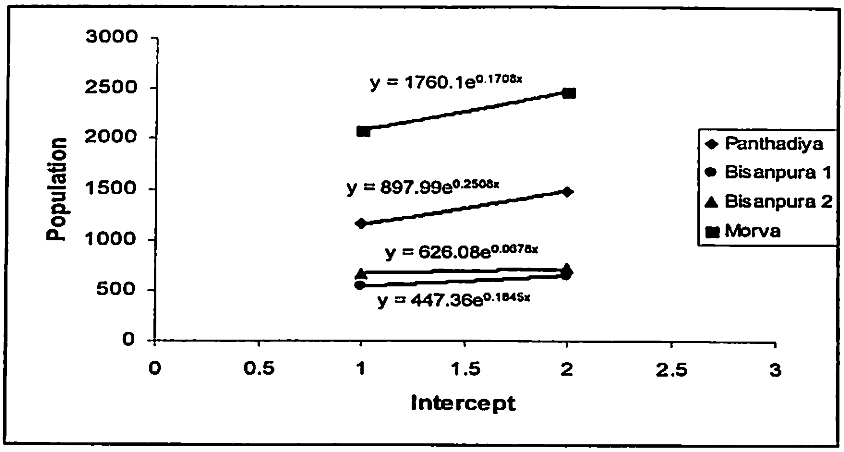

Figure 3.2 Results of Exponential Regression Analysis for Surveyed Villages

The exponential growth observed in last decade i.e. 1991-2001 is used as a basis for estimating present (i.e. 2005) and future (i.e. 2010 and 2015) populations of surveyed villages.

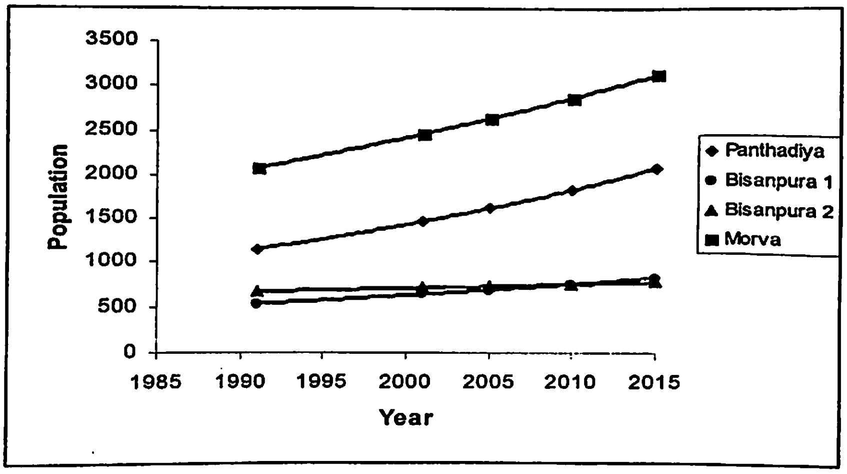

Figure 3.3 Estimated Populations of Surveyed Villages using Exponential Regression Analysis

The results of exponential regression analyses for calculating future populations are shown in Figure 3.3 and estimated populations for the surveyed villages in the present year are shown in Table 3.4.

Table 3.4 Estimated Population in the Surveyed Villages

Name of the Village	*Population as reported in Census 2001*	*Estimated population in the year 2005*
Panthadiya	1483	1640
Bisanpura 1st	647	697
Bisanpura 2nd	717	737
Morva	2477	2652

3.1.3 Collection of Primary Data through Survey

The secondary information was analysed to select households for stratified sampling (based on landholdings and community) for the energy survey. Households in the village were categorized into landless, small, medium and large farmers based on the landholdings. Under each category, households were grouped community wise, and samples were selected from each category.

3.2 DETAILED SURVEY OF ENERGY CONSUMPTION PATTERNS

The classification adopted for the survey based on landholding is: (i) landless, (ii) small farmers (0±1 ha), (iii) medium farmers (1±2.5 ha), (v) large farmers (2.5±5ha) and (vi) very large farmers (>5ha), keeping in view the fragmented landholding scenario of the village. Table 3.5 shows the demographic information of the surveyed village and distribution according to socio-economic distribution of the village. Number of households are estimated by consulting *Sarpanch* and senior citizens of respective villages.

Population to cattle ratio, as observed in Census 2001, is used as a basis to estimate number of cattle available in the base year i.e. 2005. The estimated number of cattle in the surveyed villages is shown in Table 3.5.

Table 3.5 Demography of Surveyed Villages

Name of the Village	*Landless*	*Small farmers (0±1ha)*	*Medium farmers (1±2.5ha)*	*Large farmers (2.5±5ha)*	*Very Large farmers (>5ha)*	*Number of cattle*
Panthadiya	9 (3.75%)	81 (33.75%)	103 (42.92%)	37 (15.41%)	10 (4.17%)	820
Bisanpura 1st	0 (0.00%)	58 (57.43%)	33 (32.67%)	8 (7.92%)	2 (1.98%)	389
Bisanpura 2nd	4 (2.96%)	48 (35.56%)	54 (40.00%)	19 (14.07%)	10 (7.41%)	384
Morva	5 (1.41%)	128 (36.06%)	121 (34.08%)	77 (21.69%)	24 (6.76%)	1149

It can be observed that the percentage of small and medium farmers is larger, followed by large farmers, very large farmers, and landless farmers in the surveyed villages. The percentage of small and medium farmers is more in the surveyed villages.

3.2.1 Factors influencing energy use patterns in the surveyed villages

The energy use patterns depend on distribution of households, population distribution and landholding, cropping pattern and irrigation intensity and crop residue.

3.2.1.1 Distribution of households

Figure 3.4 show the distribution of number of households against the size of the family for *Panthadiya* village. It is seen that the average size of the family is about five in all categories. The relatively flat family size distribution for very large and landless farmers is possibly due to their population in the village. Figure 3.5 show the number of households against their operational landholdings for *Panthadiya* village and reveals that about 43% of the households belong to the medium farmer category (1.00 to 2.5 ha of land).

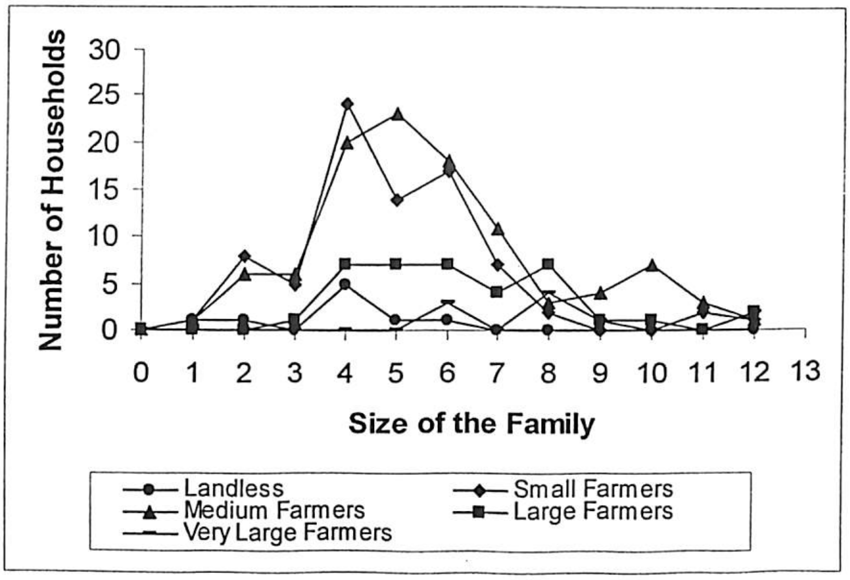

Figure 3.4 Households Distribution by Family Size for *Panthadiya* Village

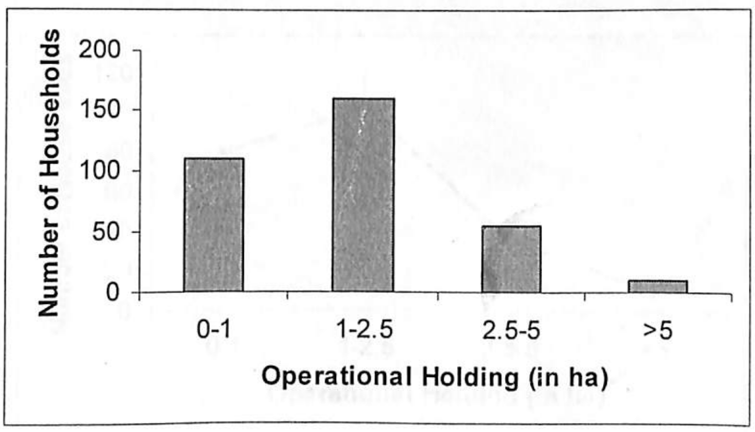

Figure 3.5 Distribution of Household by Operational Landholdings for *Panthadiya* Village

3.2.1.2 Population Distribution and Landholding

Population is an important parameter having direct impact on energy consumption, demand and supply of energy in rural regions. Agriculture being the major source of income in the study area, the size of the operational landholdings is an important parameter, which determines the demand and supply of energy, and the distribution of energy consumption. Hence, it is essential to consider the population distribution in the rural region in terms of the size of farms. For the present study, the sample households were divided into five categories, (i) landless, (ii) small farmers (0±1 ha), (iii) medium farmers (1±2.5 ha), (v) large farmers (2.5±5ha) and (vi) very large farmers (>5ha). Figure show the population distribution according to landholding. It has been observed during the survey that, households having larger operational landholding are found to consume a larger quantity of energy while the reverse is the case with households having marginal operational landholding.

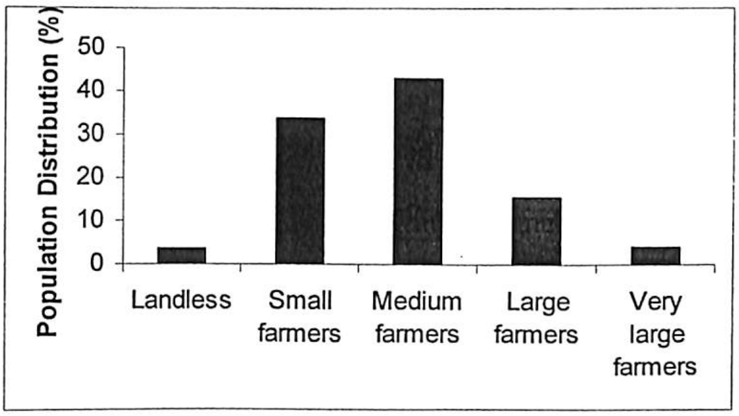

Figure 3.6 Population Distributions According to Landholdings for *Panthadiya* Village

3.2.1.3 Cropping Pattern and Irrigation Intensity

Irrigation intensity for cropping is an important factor which determines the energy requirement in agricultural operations. In the study area, the field crops are cultivated in one, two or three seasons depending upon the infrastructure facilities. For a farm cultivating field crops in more than one season, the energy demand would increase accordingly.

Energy consumption for irrigation purely depends on the nature of the water source and the irrigation methods employed. The major source of irrigation in the study area is ground water. Since, the ground water is available at 250 feet below the ground level, installation of electric pump sets lead to an increased consumption of commercial energy. The electric pumps which are used in the region are of 12.5 hp capacity. Table 3.6 shows number of tube-wells used for irrigation purpose in the surveyed villages.

Table 3.6 Number of Tube-wells used in Surveyed Villages

Name of the Village	*Number of tube-wells*
Panthadiya	58
Bisanpura 1st	21
Bisanpura 2nd	24
Morva	72

(Source: RSEB, Pilani 2005)

3.2.1.4 Crop Residues

The ratio of the main product to the by-product varies due to difference in varities of crop, cultivation practices, and application of different types of technologies at the farm level (Ramchandra, 2001). The ratio for crop residues is calculated on the basis of the production of the main products and their by-products for analysis. The main crops in the study area are mustard, and wheat. It is observed that residue of mustard is used for cooking and heating end-uses.

3.2.2 Equations Employed for Calculating the End-use Energy Requirements

The detailed survey questionnaire is developed to collect relevant data for various end-use energy requirements per household as shown in Appendix I. To calculate energy requirement per household, primary survey is conducted by visiting these villages. End-use energy requirements are categorized as cooking, lighting, pumping, heating, cooling, and appliances.

The primary survey has considered only six important end-uses and for each end-use commonly used devices have been considered. The equations used to compute the energy requirements for device-end use combination are as follows:

Energy consumption = (Number of devices used) x (energy consumed for 1 hour of usage) x (Average number of hours of usage of the device) x (Number of days of usage in a year)

Computation of Per Capita Energy Consumption (PCEC)

Per capita energy consumption is calculated by using following formula.

$PCEC = EC/p$

where, EC = energy consumed per day and p = number of adult equivalents, for whom the energy is used. (Ramachandra *et al.*, 2001)

Assumptions made while computation of PCEC are:

1. More than one type of fuel is used for cooking and heating end-use in many households. The daily consumption of different fuels is calculated separately.

2. These daily consumption values in each household are then converted into equivalent energy (MJ/kg) using the gross calorific value of each type of residue.

3. The daily energy consumption of each household is further converted to per adult energy consumption using the adult equivalent of the number of people, which is computed assuming the conversion factors shown in Table 3.7

4. The data on energy consumption is grouped on the basis of landholding category. Then the average values for each end-use are calculated.

Table 3.7 Standard Adult Equivalents used in Analysis

Family Size	*Standard Adult Equivalent*
Men 18-59 yr	1
Women 18-59 yr	0.8
Men >59 yr	0.8
Women >59 yr	0.8
Boys 5-18 yr	0.5
Girls 5-18 yr	0.5
Kids 1-5 yr	0.35
Child <1 yr	0.25

(Source: Ramachandra *et al.*, 2001)

3.2.2.1 Cooking Energy End-use

The energy sources considered for the end-use are firewood, dung cake and LPG. The devices considered are ordinary *chulah,* and LPG stoves. Cooking energy requirement per person is estimated on the basis of amount of firewood, dung cakes consumed per day, and time duration for consumption of one LPG cylinder.

Cooking energy requirement per family is calculated by using following equations. It is assumed that usage of cooking end-use for 365 days in a year.

Amount of firewood consumed = $\sum$ (Amount of firewood consumed per day) x (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

Amount of dung cake consumed = $\sum$ (Amount of dung cake consumed per day) x (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

Amount of LPG consumed = $\sum$ (Time for consumption of one LPG cylinder) (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

The daily consumption of energy source for cooking in each household is further converted to PCEC.

3.2.2.2 Lighting Energy End-use

The energy sources considered for the end-use are kerosene and electricity and the devices considered for illumination are lanterns, incandescent bulbs (40 W, 60 W, 100 W, and 15 W), and tube lights (40 W). Lighting energy requirement per person is estimated on the basis of number of incandescent bulbs, tube lights, their wattages and usage period.

Lighting energy requirement per family is calculated by using following equations. The average usage period of 6 hours is assumed for electricity consumption based on the observations during the survey.

Amount of Kerosene consumed = $\sum$ (Amount of kerosene consumed per day) x (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

Electricity consumed for Incandescent Bulbs = (Number of bulbs of each type) x (Electricity consumed for one hour of usage) x (Average number of hours of usage) x (End-use device efficiency) x (Number of days of usage in the year)

Electricity consumed for Tube lights = (Number of tube lights) x (Electricity consumed for one hour of usage) x (Average number of hours of usage) x (End-use device efficiency) x (Number of days of usage in the year)

The daily consumption of energy source for lighting in each household is further converted to PCEC.

3.2.2.3 Pumping Energy End-use

Pumping end-use is considered for irrigation purpose. The energy source considered for the end-use is electricity. Pumping energy requirement per household is estimated on the basis of number of pump sets used for irrigation purposes, their wattages and usage period.

Pumping energy requirement is calculated by using following equation. The usage period of 8 hours and 200 days in a year is assumed on the basis of present irrigation pattern of the region.

Amount of Electricity used = (Number of Electric Pumps of each type) x (Electricity consumption for one hour of usage of each pimp) x (Number of hours of usage of each pump) x (End-use device efficiency) x (Number of days of usage in the year)

3.2.2.4 Heating Energy End-use

Heating end-use is considered for water heating and room heating purposes. The energy sources considered for the end-use are firewood, dung cakes and electricity. The devices considered are ordinary *chulah*, and electric geysers. Heating energy requirement per person is estimated on the basis of water heater/electric rod, firewood and dung cake consumed per day for water heating application.

Heating energy requirement per family is calculated by using following equations. Available electric heating sources such as immersion rod (mainly 1000W or 1500W), and geyser (3000W) are considered in the study.

Amount of firewood consumed = (Amount of firewood consumed per day) x (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

Amount of dung cake consumed = (Amount of dung cake consumed per day) x (Net calorific value) x (End-use device efficiency) x (Number of days in the year)

Amount of Electricity used = (Number of immersion-rods or geysers) x (Electricity consumption for one hour of usage) x (Number of hours of usage) x (End-use device efficiency) x (Number of days of usage in the year)

The daily consumption of energy source for heating in each household is further converted to PCEC.

3.2.2.5 Cooling Energy End-use

Cooling end-use is considered for conditioning the room and for refrigeration purpose. The energy source considered for the end-use is electricity. The devices considered are refrigerator, air coolers, and electric fans. Cooling energy requirement per person is estimated on the basis of number of fans, coolers and refrigerators used their wattages and usage period.

Cooling energy requirement per family is calculated by using following equation.

Amount of Electricity used = (Number of cooling devices used) x (Electricity consumption for one hour of usage of each device) x (Number of hours of usage of each device) x (End-use device efficiency) x (Number of days of usage in the year)

The daily consumption of energy source for cooling end-use in each household is further converted to PCEC.

3.2.2.6 Appliances Energy end-use

Appliance end-use is considered for electrical appliances such as mixer, television, music system, electric iron and curd churner. The energy source considered for the end-use is electricity. Appliance energy requirement per person is estimated on the basis of use of television, mixer, music system, washing machine, curd churner, and washing machine used their wattages, and usage period.

Cooling energy requirement per family is calculated by using following equation.

Amount of Electricity used = (Number of Appliances used) x (Electricity consumption for one hour of usage of each electric appliance) x (Number of hours of usage of each appliance) x (End-use device efficiency) x (Number of days of usage in the year)

The quantity of each type of appliance is dependent on size of family and income of the family. The daily consumption of energy source for cooling end-use in each household is further converted to PCEC.

3.3 END-USE ENERGY REQUIREMENTS OF SURVEYED VILLAGE

The average estimated energy requirement per person for each end-use in the surveyed villages is calculated using equations given in the previous section and the results of analysis is shown in Table 3.8 and in Appendix II.

Table 3.8 Estimated Actual End-use Energy Requirements for Surveyed Villages

Energy End-use	*Panthadiya*		*Bisanpura 1st*		*Bisanpura 2nd*		*Morva*	
	Energy requirement per person, per day, kWh	*Annual energy requirement MWh/yr*	*Energy requirement per person, per day, kWh*	*Annual energy requirement MWh/yr*	*Energy requirement per person, per day, kWh*	*Annual energy requirement MWh/yr*	*Energy requirement per person, per day, kWh*	*Annual energy requirement MWh/yr*
Cooking	1.495	0.895×10^3	1.499	0.381×10^3	1.463	0.394×10^3	1.455	1.409×10^3
Lighting	0.10	0.060×10^3	0.14	0.036×10^3	0.12	0.032×10^3	0.11	0.107×10^3
Pumping	---	*0.790×10^3	---	#0.286×10^3	---	$$0.327 \times 10^3$	---	!0.980×10^3
Heating	0.0002	0.120	0.0002	0.051	0.0002	0.054	0.0002	0.194
Cooling	0.212	0.127×10^3	0.344	0.088×10^3	0.274	0.074×10^3	0.207	0.200×10^3
Appliances	0.055	0.033×10^3	0.082	0.021×10^3	0.061	0.016×10^3	0.052	0.050×10^3

* *58 tube-well pumps of 12.5 hp used for 5 hours per day*
\# *21 tube-well pumps of 12.5 hp used for5 hours per day*
\$ *24 tube-well pumps of 12.5 hp used for 5 hours per day*
! *72 tube-well pumps of 12.5 hp used for 5 hours per day*

Figure 3.7 show present energy consumption pattern in *Panthadiya village*. It can be observed that 41% of total energy consumed is used for agricultural pumping end-use due to irrigation pattern existing in the village.

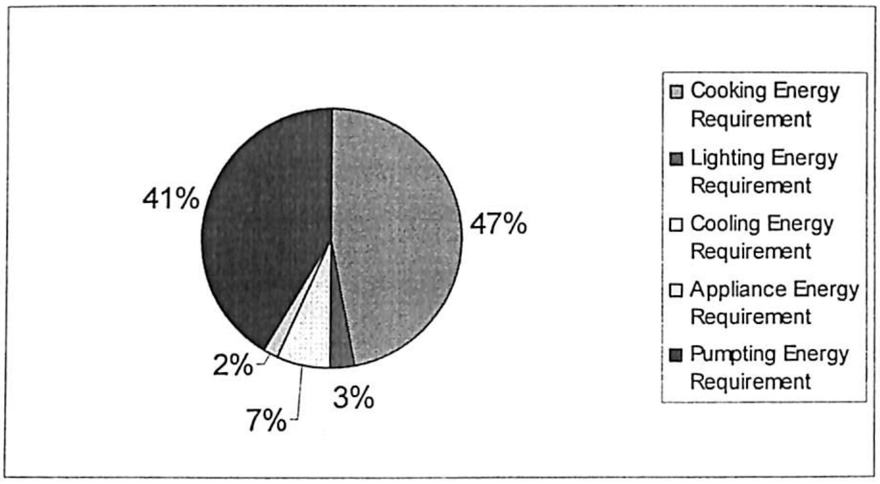

Figure 3.7 Present Energy Consumption Pattern in *Panthadiya* Village

Figure 3.8 show the distribution of energy in household end-uses. It can be seen that cooking end-use contributes for major energy consumption, followed by cooling, lighting and appliance end-uses. Heating end-use contributes for very less energy consumption; this may be due to lower utilization of firewood for heating.

The per capita cooking energy requirement recommended by the Advisory Board of Energy (India) in 1991 is 0.594 kWh/day (Sinha and Kandpal, 1991), which is found to have increased to 1.495 kWh/day. This is attributed to change in cooking pattern over the years (Devdas, 2000b). The per capita cooling energy and heating energy consumption is observed to be 0.212 kWh/day and 0.0002 kWh/day, since the region is falling under semi-arid zone of desert (CAZRI, 2004).

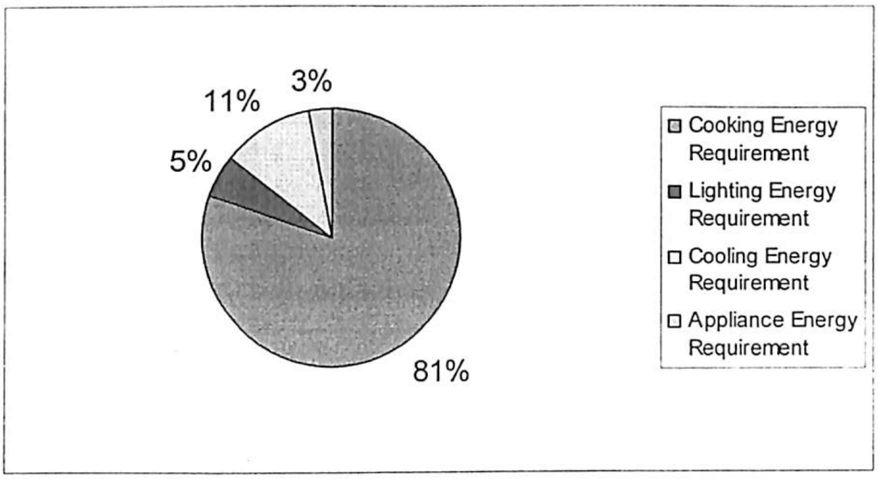

Figure 3.8 Present Household Energy Consumption Pattern for *Panthadiya* Village

3.4 ENERGY RESOURCE AVAILABILITY OF SURVEYED VILLAGE

The survey questionnaire was also developed to estimate energy resource availability of the villages. Biogas availability in the village is calculated on the basis of number of cattle and the dung available. It is assumed that on an average, two cattles can provide 25 kg of dung or 1 m^3 of biogas or 20.14 MJ of energy per day (Ramanathan and Ganesh, 1993). During the field visits, it is also observed that in most of the families 10-25% dung available is used for making dung cakes and 75-90% is then used in agriculture. But the cooking pattern of the region indicates that the dung cakes are not fully consumed for the cooking and heating applications. Therefore, it is assumed that 15% of the dung cakes produced are used for cooking and heating applications. The remaining 85% of dung available can be utilized for biogas production. Table 3.9 shows the estimated dung available, dung cake consumption and biogas availability per day for the surveyed villages.

Table 3.9 Estimated Dung-cake Consumption and Biogas Availability in Surveyed Villages

Name of the Village	*Number of cattle*	*Dung available, kg/year*	*Dung cake consumption, MJ/year*	*Biogas availability, MJ/year*
Panthadiya	820	3.74×10^6	5.61×10^6	2.56×10^6
Bisanpura 1st	389	1.78×10^6	2.67×10^6	1.22×10^6
Bisanpura 2nd	384	1.75×10^6	2.63×10^6	1.20×10^6
Morva	1149	5.24×10^6	7.86×10^6	3.59×10^6

Biomass energy resource is calculated on the basis of amount of firewood and agricultural residue consumed in a socio-economic group and its corresponding calorific value. The availability of firewood is calculated on the basis of the number of *Prosopis Cineraria* commonly known as *Jati* trees in the area and their annual yield. It is estimated that one *Jati* tree yields around 50 kg/year and there are on an average 25 trees/hectare. Therefore, number of *Jati* trees in the village can be estimated and their yield is shown in the Table 3.10. It is observed that along with the firewood, agricultural residue of Mustard is also used for cooking and heating end-uses. The Mustard is cultivated in 35% of the land available in the region and residue produced per hectare of Mustard cultivated is 200 kg. It is also observed that most of the times the biomass requirement is met locally. On an average, 1 kg (dry) of biomass produces 1.66 to 2.101 m^3 of producer gas in a circulating fluidized bed gasifier (Bingyan *et al.*, 1994) and the calorific value of the gas generated varies from 6.94 to 7.26 MJ/m^3. Table 3.10 shows the estimated biomass energy availability per year for the surveyed villages.

Table 3.10 Estimated Biomass Energy Available in Surveyed Villages

Name of the Village	*Total land (in hectares)*	*Irrigated land (in hectares)*	*Firewood availability, tons/year*	*Agricultural residue, tons/year*	*Biomass energy available, MJ/year*
Panthadiya	522	481	602	58.92	9.26×10^6
Bisanpura 1st	190	169	212	20.70	3.26×10^6
Bisanpura 2nd	185	167	209	20.46	3.21×10^6
Morva	857	733	917	89.79	14.10×10^6

The estimated actual energy requirement for household and agriculture end-uses and energy resource availability of the surveyed villages is used for energy resource allocation. The details of methodology adopted for energy resource allocation and results for present energy resource allocation in *Panthadiya* village are presented in the next chapter.

Chapter 4: Energy Resource Allocation

In this chapter, the methodology adopted for energy resource allocation in Integrated Renewable Energy System (IRES) design for the surveyed villages of Jhunjhunu district of Rajasthan is described. The model developed for energy resource allocation is used for determining energy resource allocation for meeting present energy needs. Six different scenarios are developed by considering different priorities of the objective functions. An optimal scenario for implementation is searched from among the developed scenarios by evaluating these on the basis of associated cost and emissions. The methodology adopted for the energy resource allocation is given in Figure 4.1.

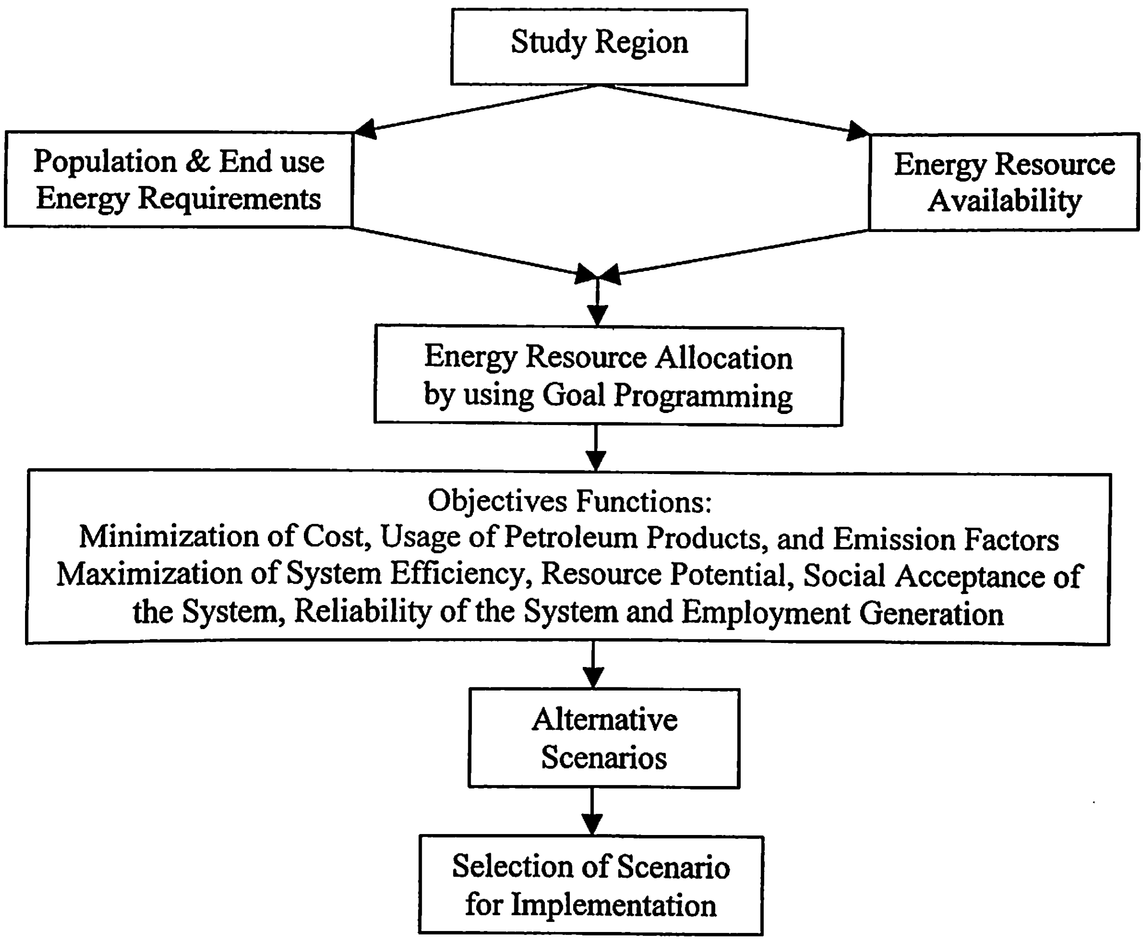

Figure 4.1 Methodology Adopted for Energy Resource Allocation

4.1 INTRODUCTION TO INTEGRATED RENEWABLE ENERGY SYSTEM

Environmental concerns and the ever-increasing need for energy, coupled with a steady progress in renewable energy technologies are opening up new opportunities for utilization of renewable energy resources. Integrated renewable energy systems, defined as a combination of renewable and conventional energy technologies, are known to offer, a higher degree of operating flexibility. In many situations, these are likely to be competitive with conventional application technologies achieving, ambitious environmental goals. The environmental considerations are particularly in favour of use of integration of renewable energy systems (Rozakis *et al.*, 1997).

The IRES for rural environ takes into account the climatic conditions and cultivation patterns of local farms and the system's operating flexibility makes it suitable for satisfying a particular energy demand patterns at low cost (Rozakis *et al.*, 1997).

The region-wise development of IRES involves assessment of existing demand and future demand, and evaluation of present and future resource availability, engineering and technical feasibility and reliability, economic attractiveness of systems on longer term basis.

Also, it is important to study the optimal mix of renewable energy sources in order to evaluate the techno-economic viability of IRES. Detailed statistical analysis of availability of renewable energy resources at a regional level along with identification of possible complementary characteristics of renewable energy sources is required for evaluating performance of IRES on both short-term and long-term basis (Sahin, 2000).

4.2 INTEGRATED RENEWABLE ENERGY SYSTEM MODEL DEVELOPMENT

In this section, methodology adopted for energy resource allocation along with the mathematical formulation of the problem is discussed.

4.2.1 Methodology for Energy Resource Allocation

The methodology involves development of model for optimal energy resources allocation for the different end-uses: The resource-end-use combination is selected on the basis of feasibility of energy resource utilization for particular end-use application (Ramanthan and Ganesh, 1995). In all eleven energy resources based on the feasibility for utilization for six different end-uses have been considered, and 41-resource end-use combinations have been investigated. These combinations are shown in Table 4.1.

Table 4.1 Energy Resource - End-use Combinations

Energy Resources	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Dung cake	1	---	---	23	---	---
Biomass	2	---	---	24	---	---
LPG	3	---	---	---	---	---
Kerosene	4	12	---	---	---	---
Biogas	5	13	---	25	---	---
Solar Thermal	6	---	---	26	---	---
*Biogas electricity**	7	14	19	27	32	37
*Biomass electricity**	8	15	20	28	33	38
PV electricity	9	16	--	29	34	39
Diesel electricity	10	17	21	30	35	40
Grid electricity	11	18	22	31	36	41

** electricity generated by biogas/biomass gasifier engine*

A generalized model is developed for optimization: The objectives of optimization are of minimization or maximization in nature. The objectives of minimization pertain to cost of energy, usage of petroleum products, and environment emissions such as CO_x, SO_x, and NO_x, associated with energy source-end-use combination. The objectives for maximization pertain to end-use system efficiency, reliability of the system, local resource availability, employment generation, and social acceptance of the system.

The model is required to optimize energy resource allocation subject to constraints such as end-use demand, technical limit for energy resource utilization for specific end-use and energy resource availability. The constraints considered for certain activities in the model represent realistic utilization of energy resources.

Thus, the model developed for optimization has more than one objective and therefore cannot be solved by simple linear programming technique. In order to determine the optimum resource allocation with respect to all objectives taken into account, linear goal programming technique is used, wherein, the multi-objective optimization is carried out. The model has been solved using the WINQSB package on computer (Mezher *et al.*, 1998; Ramanathan and Ganesh, 1993).

The QSB (Quantitative Systems for Business) is developed by Yih-Long Chang. The software package contains the widely used problem solving algorithms in operations research and management science. The WINQSB is the windows version of the QSB software package. In the present study version 1.00 is used and the sample result is shown in Appendix III.

The alternative scenarios are generated referring to economic, security-social acceptance and environment objectives, on the basis of present energy demand subject to energy resource availability. In economic scenario, set goals are minimization of cost, maximization of system efficiency and maximization of employment generation. In security-social acceptance scenario, set goals are minimization of imported petroleum products, maximization of use of local resources and social acceptance of energy system. In environment scenario, set goals are minimization of CO_X, SO_X and NO_X. The scenarios are compared with respect to the associated cost and environmental emissions. The feasible scenario for implementation is the one associated with minimum cost and environmental emissions.

4.2.2 Mathematical Representation of Model

The mathematical representation of the model is in terms of expressions stating objectives and constraints, as follows:

The objective functions are:

1. Minimum cost: The cost refers to the actual cost of energy delivered at the end-use point. The objective function is represented as:

$$\text{Min} \sum_{i=1}^{41} (C_i X_i) \qquad (1)$$

where, C is the unit cost of energy at end-use point, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

2. Maximum system efficiency: The system efficiency of a particular resource-end-use combination is the actual efficiency of energy utilization, including the efficiency of production and distribution, and end-use device efficiency. The efficiency of production and distribution is referred to as the external efficiency. The system efficiency is computed as a product of external and end-use device efficiency. The objective function is represented as:

$$\text{Max} \sum_{i=1}^{41} (\eta_i X_i) \tag{2}$$

where, η the efficiency of end-use utilization of energy, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

3. Maximum reliability: The term reliability refers to the availability of energy source for utilization. In case of local energy resources, it is always unity. In case of electricity generation, it depends on reliability of energy system for power generation. The objective function is represented as:

$$\text{Max} \sum_{i=1}^{41} (R_i X_i) \tag{3}$$

where, R the reliability of the system, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

4. Maximum utilization of local resources: The use of local resources should be maximized to reduce dependence on commercial energy sources and to achieve self dependence in energy sources utilization. The objective function is represented as:

$$\text{Max} \sum (X_i) \tag{4}$$

where, X is the quantum of energy used at the end-use point and subscript i denotes the energy resource-end-use combinations for dung, biogas, biomass, and solar energy sources.

5. Minimum use of petroleum products: The use of petroleum products should be minimized to reduce dependence on imported commercial energy sources. The objective function is represented as:

$$\text{Min} \sum (X_i) \tag{5}$$

where, , X is the quantum of energy used at the end-use point and subscript i denotes the energy resource-end-use combinations for LPG, kerosene, and diesel energy source.

6. Maximum employment generation: When energy is considered as a sub-system of the economic system, it facilitates the employment generation. The employment generation opportunities should be maximized. The objective function is represented as:

$$\text{Max} \sum_{i=1}^{41} (e_i X_i) \tag{6}$$

where, e the employment generation factor, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

7. Maximizing social acceptance of energy system: The social acceptance of energy systems is important while promoting energy resource use. The objective function is represented as:

$$\text{Max} \sum_{i=1}^{41} (S_i X_i) \tag{7}$$

where, S is the social acceptance of energy system, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

8. Minimum emissions: Three major pollutants are investigated to study the impact of human activities on environment (Mezher *et al.*, 1998). These are carbon oxides (CO and CO_2), sulfur oxides, and nitrogen oxides. The objective functions are represented as:

Minimization of CO_x emission (i.e. $\sum_{i=1}^{41}(CO_i X_i)$) (8)

Minimization of SO_x emission (i.e. $\sum_{i=1}^{41}(SO_i X_i)$) (9)

Minimization of NO_x emission (i.e. $\sum_{i=1}^{41}(NO_i X_i)$) (10)

where, CO, SO, and NO, are the emission factors in resource-end-use combination, X is the quantum of energy used at the end-use point and subscript i denotes the end-use resource combination.

The constraints are:

i) Cooking energy requirement (i.e. $\sum_{i=1}^{11}(X_i) \geq$ Total cooking energy requirement) (11)

ii) Lighting energy requirement (i.e. $\sum_{i=12}^{18}(X_i) \geq$ Total lighting energy requirement) (12)

iii) Pumping energy requirement (i.e. $\sum_{i=19}^{22} x_i \geq$ Total pumping energy requirement) (13)

iv) Heating energy requirement (i.e. $\sum_{i=23}^{31} x_i \geq$ Total heating energy requirement) (14)

v) Cooling energy requirement (i.e. $\sum_{i=32}^{36} x_i \geq$ Total cooling energy requirement) (15)

vi) Appliances energy requirement (i.e. $\sum_{i=37}^{41} x_i \geq$ Total appliances energy requirement) (16)

vii) Limit solar thermal usage for cooking:

The solar thermal cookers cannot cook all varieties of food and therefore total cooking requirement cannot be met. As such, solar thermal cookers can be used for low-temperature cooking purposes only, which form approximately 20% of the total cooking requirement (Sinha and Kandpal, 1991a). Therefore, the potential limit for the use of solar thermal cookers is assumed to be 20% of the total cooking energy requirement. The constraint is:

$$\sum(X_6) \leq 20\% \text{ of the total cooking energy requirements} \tag{17}$$

viii) Limit for use of dung cake for cooking and heating:

Cooking patterns of the region indicate that the dung cakes are not fully consumed for the cooking and heating applications. During the survey, it is observed that in most of the families 10-25% dung available is used for making dung cakes. Therefore, it is assumed that 15% of the dung cakes produced are used for cooking and heating applications. Therefore, constraint function is

$\sum\left(\frac{X_i}{\eta_i}\right) \leq 15\%$ of the dung availability, where $i=$ *dung cake for cooking and heating end-use.* (18)

ix) Potential limit for biogas energy (i.e. $\sum\left(\frac{X_i}{\eta_i^{'}}\right) \leq$ Available biogas energy, where *i = energy resource-end-use combinations for biogas energy source, and* η' = *end-use device efficiency*) (19)

x) Potential limit for biomass energy (i.e. $\sum\left(\frac{X_i}{\eta_i^{'}}\right) \leq$ Available biomass energy, where i = *energy resource-end-use combinations for biomass energy source and* η' = *end-use device efficiency*) (20)

4.2.3 Mathematical Programming

The goal of linear programming is to determine the values of decision variables that maximize or minimize a linear objective function, where the decision variables are subject to linear constraints. A linear programming problem is a special case of a general constrained optimization problem. In the general setting, the goal is to find a point minimizes/maximizes the objective function and at the same time satisfies the constraints. Efficient methods for solving linear programming problems became available in the late 1930s (Chong and Zak, 2004; Trzaskalik and Michnik, 2001). In the recent past, multiple objective linear programming became popular and is applied to water resource management (Raju and Pillai, 199), production planning (Sangwan and Kodali, 2003), power system planning (Kavrakoglu, 1983; Dhillon *et al.*, 2001) etc.

The objective functions used in the model are linear in nature. These objective functions can be individually solved by single objective linear optimization technique. In some cases, there may be more than one competing objective (or goal) and we need to trade-off objectives against each other. In such situations, to account for objective functions, a multi-objective linear programming called goal programming is used.

The present optimization model consists of 10 objective functions subject to 10 constraints. Therefore this type of problem can be solved by using goal programming technique. In goal programming technique, objective functions are referred to as goals and these goals may be either overachieved or underachieved. The deviation variables, *w,* are defined to represent the overachievement or underachievement of the goals as follows:

The basic approach of goal programming is to establish a specific numeric goal for each objective, and then seek a solution that corresponds to minimum weighted sum of deviation of the objective functions from their respective goals. Further, the pre-emptive goal programming is used, where there is a hierarchy of priority levels for the goals, so that the objective functions are optimized in the order of priority. Based on the objectives and constraints provided in the problem formulation section, a pre-emptive goal programming model has been developed, first by defining goals for each of the objectives, and then by minimizing the sum of the deviation variables. The objective function is solved individually and the optimized value for each objective is used as the corresponding goal.

The goal programming model is described as follows:

$$\text{Minimize} \sum d_j^- + d_j^+ \qquad \text{where } (j = 1, 2 \ldots 10)$$

Subject to,

$$\left(\sum_{i=1}^{41} (C_i X_i)\right) + w_1 d_1^- - w_1 d_1^+ = b_1 \qquad (1)$$

$$\left(\sum_{i=1}^{41} (\eta_i X_i)\right) + w_2 d_2^- - w_2 d_2^+ = b_2 \qquad (2)$$

$$(\sum_{i=1}^{41}(R_i X_i)) + w_3 d_3^- - w_3 d_3^+ = b_3 \quad (3)$$

$$(\sum(X_i)) + w_4 d_4^- - w_4 d_4^+ = b_4 \quad (4)$$

$$(\sum(X_i)) + w_5 d_5^- - w_5 d_5^+ = b_5 \quad (5)$$

$$(\sum_{i=1}^{41}(e_i X_i)) + w_6 d_6^- - w_6 d_6^+ = b_6 \quad (6)$$

$$(\sum_{i=1}^{41}(S_i X_i)) + w_7 d_7^- - w_7 d_7^+ = b_7 \quad (7)$$

$$(\sum_{i=1}^{41}(CO_i X_i)) + w_8 d_8^- - w_8 d_8^+ = b_8 \quad (8)$$

$$(\sum_{i=1}^{41}(SO_i X_i)) + w_9 d_9^- - w_9 d_9^+ = b_9 \quad (9)$$

$$(\sum_{i=1}^{41}(NO_i X_i)) + w_{10} d_{10}^- - w_{10} d_{10}^+ = b_{10} \quad (10)$$

$$\sum_{i=1}^{11}(X_i) \geq \text{Total cooking energy requirement} \quad (11)$$

$$\sum_{i=12}^{18}(X_i) \geq \text{Total lighting energy requirement} \quad (12)$$

$$\sum_{i=19}^{22} x_i \geq \text{Total pumping energy requirement} \quad (13)$$

$$\sum_{i=23}^{31} x_i \geq \text{Total heating energy requirement} \quad (14)$$

$$\sum_{i=32}^{36} x_i \geq \text{Total cooling energy requirement} \quad (15)$$

$$\sum_{i=37}^{41} x_i \geq \text{Total appliances energy requirement} \quad (16)$$

$$\sum(X_6) \leq 20\% \text{ of the total cooking energy requirement} \quad (17)$$

$$\sum\left(\frac{X_i}{\eta_i}\right) \leq 7.5\% \text{ of the dung availability} \quad (18)$$

$$\sum\left(\frac{X_i}{\eta_i^{'}}\right) \leq \text{Available biogas energy} \qquad (19)$$

$$\sum\left(\frac{X_i}{\eta_i^{'}}\right) \leq \text{Available biomass energy} \qquad (20)$$

where, b_j = goal value for the objective, j

d_j^- = underachievement of goal, d_j^+ = overachievement of goal

w_j = weighing factors for d_j^- and d_j^+ = $b_j - L_j$

L_j = worst possible value for objective, j

= minimum value for objective, j (for maximization type objectives)

= maximum value for objective, j (for minimization type objectives)

4.3 DATA EMPLOYED IN THE MODEL

The cost of energy from a source is calculated as follows:

$$Actual\ cost\ incurred = \frac{Cost(Rs/kg)}{CalorificValue(MJ/kg)} x\ 3.6 \qquad (Rs/kWh)$$

The present cost of energy resources in Rs/kg and their corresponding calorific value is shown in Table 4.2.

Table 4.2 Present Cost of Energy Resource and its Calorific Value

Energy Source	*Present cost, Rs/kg*	*Calorific value*, MJ/kg*
Dung cake	1.00	11.76
Biomass	3.00	15.00
LPG	21.80	46.00
Kerosene	10.00	44.00
Biogas	1.50[a]	20.14[a]

** Cooking fuel options help guide, United Nations Joint Logistic Centre*

a Rubab and Kandpal, 1999

The subsidized cost of box type solar cooker is in the range of Rs 800-1000 (MNES, 2004) with power capacity of 250W and life of 10 years and usage of 4 hrs per day for 270 clear days in the year, results in cost for cooking end-use and the same value is assumed for heating end-use (Iniyan and Sumathy, 2000).

The unit cost of energy in Rs/kWh for resource-end use combinations, used in the optimization model using the above equation is shown in Table 4.3.

Table 4.3 Cost of Energy Resource associated with different - End-use Combinations (Rs/kWh)

Energy resources	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Dung cake	0.31	---	---	0.31	---	---
Biomass	0.72	---	---	0.72	---	---
LPG	1.71	---	---	---	---	---
Kerosene	0.82	0.82	---	---	---	---
Biogas	0.27	0.27	---	0.27	---	---
Solar Thermal	0.37	---	---	0.37	---	---
Biogas electricity [a]	1.25	1.25	1.25	1.25	1.25	1.25
Biomass electricity [b]	2.50	2.50	2.50	2.50	2.50	2.50
PV electricity [b]	15.00	15.00	---	15.00	15.00	15.00
Diesel electricity [d]	15.00	15.00	15.00	15.00	15.00	15.00
Grid electricity [c]	3.00	3.00	0.75	3.00	3.00	3.00

[a] *Iniyan and Sumathy, 2000*
[b] *MNES, 2004*
[c] *Based on present State Electricity Board charges for rural households and irrigation end-uses*
[d] *Estimated on the basis of present cost of diesel*

The energy system efficiency is calculated by multiplying external efficiency of the energy source and end-use device efficiency. External efficiency is the system efficiency just before the end-use point. The energy system efficiency for resource-end use combinations, is used in the optimization model are shown in Table 4.4.

Table 4.4 External Efficiency, End-use efficiency and System Efficiency for different Energy Resource -End-use Combinations

		Cooking		*Lighting*		*Pumping*		*Heating*		*Cooling*		*Appliances*	
Energy resources	***External efficiency[a]***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***
Dung cake	95.00[b]	17.00	16.15	---	---	---	---	17.00	16.15	---	---	---	---
Biomass	95.00[c]	17.00	16.15	---	---	---	---	17.00	16.15	---	---	---	---
LPG	72.00[d]	50.00	36.00	---	---	---	---	---	---	---	---	---	---
Kerosene	72.00[d]	45.00	32.40	1.00	0.72	---	---	---	---	---	---	---	---
Biogas	88.00[d]	50.00	44.00	1.00	0.88	---	---	50.00	44.00	---	---	---	---
Solar Thermal	---[e]	100.00	40.00	---	---	---	---	100.00	40.00	---	---	---	---
Biogas electricity	35.20[c]	80.00	28.16	40.00	14.08	80.00	28.16	60.00	21.12	60.00	21.12	60.00	21.12
Biomass electricity	27.36[c]	80.00	21.89	40.00	10.94	80.00	21.89	60.00	16.42	60.00	16.42	60.00	16.42
PV electricity	15.00[f]	80.00	12.00	40.00	6.00	---	---	60.00	9.00	60.00	9.00	60.00	9.00
Diesel electricity	28.80[c]	80.00	23.04	40.00	11.52	80.00	23.04	60.00	17.28	60.00	17.28	60.00	17.28
Grid electricity	23.00[c]	80.00	18.40	40.00	9.20	80.00	18.40	60.00	13.80	60.00	13.80	60.00	13.80

[a] *External efficiency is the system efficiency just before the end-use point.*
[b] *Assumed value*
[c] *Based on Ref. [Ramanthan and Ganesh, 1995a,b].*
[e] *Solar thermal does not have an external efficiency, since it comes from the Sun.*
[f] *Based on a 50 kW or 5kW solar photovoltaic system [Mezher1998].*
[g] *Based on Ref. [Ramanathan and Ganesh, 1995a,b;, Mezher, 1998].*

Table 4.4 External Efficiency, End-use efficiency and System Efficiency for different Energy Resource -End-use Combinations

		Cooking		*Lighting*		*Pumping*		*Heating*		*Cooling*		*Appliances*	
Energy resources	***External efficiency[a]***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***	***End use device efficiency[g]***	***System efficiency***
Dung cake	95.00[b]	17.00	16.15	---	---	---	---	17.00	16.15	---	---	---	---
Biomass	95.00[c]	17.00	16.15	---	---	---	---	17.00	16.15	---	---	---	---
LPG	72.00[d]	50.00	36.00	---	---	---	---	---	---	---	---	---	---
Kerosene	72.00[d]	45.00	32.40	1.00	0.72	---	---	---	---	---	---	---	---
Biogas	88.00[d]	50.00	44.00	1.00	0.88	---	---	50.00	44.00	---	---	---	---
Solar Thermal	---[e]	100.00	40.00	---	---	---	---	100.00	40.00	---	---	---	---
Biogas electricity	35.20[c]	80.00	28.16	40.00	14.08	80.00	28.16	60.00	21.12	60.00	21.12	60.00	21.12
Biomass electricity	27.36[c]	80.00	21.89	40.00	10.94	80.00	21.89	60.00	16.42	60.00	16.42	60.00	16.42
PV electricity	15.00[f]	80.00	12.00	40.00	6.00	---	---	60.00	9.00	60.00	9.00	60.00	9.00
Diesel electricity	28.80[c]	80.00	23.04	40.00	11.52	80.00	23.04	60.00	17.28	60.00	17.28	60.00	17.28
Grid electricity	23.00[c]	80.00	18.40	40.00	9.20	80.00	18.40	60.00	13.80	60.00	13.80	60.00	13.80

[a] *External efficiency is the system efficiency just before the end-use point.*
[b] *Assumed value*
[c] *Based on Ref. [Ramanthan and Ganesh, 1995a,b].*
[e] *Solar thermal does not have an external efficiency, since it comes from the Sun.*
[f] *Based on a 50 kW or 5kW solar photovoltaic system [Mezher1998].*
[g] *Based on Ref. [Ramanathan and Ganesh, 1995a,b;, Mezher, 1998].*

The reliability factor is taken to be 0.1 for 10000 hours of solar PV system operation and 0.9 for 10000 hours of biomass and biogas energy systems operation, is used in the model (Iniyan and Sumathy, 2000). The reliability factor of 0.9 is assumed for diesel and grid electricity. The reliability of local energy resources based on their availability is assumed to be 1 and that of commercial energy resources is assumed to be 0.9.

Table 4.5 shows employment generation potential in terms of number of people employed in developing various energy resources and the total consumption of energy resources in India (Ramanthan and Ganesh, 1995). It is seen that, for every million kWh of coal energy consumed, on an average, 1.947 persons were employed. Considering the same values for consumption by the household sector, the employment potential per million kWh of the net coal energy consumed has been calculated for accounting system efficiency. The results of Number of Employees/million kWh energy source are shown in Table 4.6.

Table 4.5 Gross Employment Potential of Energy Sources

Energy source	*Number of persons employed*	*Consumption (10^9 kWh)*	*Number of employees (per million kWh)*
Coal (including soft coke and petroleum)	610,600	313.59	1.947
Petroleum and natural gas	35,629	263.92	0.135
Grid electricity	---	---	6.9
Renewable resources	2,806,000	11.22	250

(Source: Ramanthan and Ganesh, 1995)

Table 4.6 Net Employment Potential of Energy Sources as Number of Employees/million kWh

Energy resources	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Dung cake	1470	---	---	1470	---	---
Biomass	1470	---	---	1470	---	---
LPG	0.27	---	---	---	---	---
Kerosene	0.30	13.50	---	---	---	---
Biogas	500	500	---	500	---	---
Solar Thermal	0.17	---	---	0.23	---	---
Biogas electricity	312.50	625	312.50	416.67	416.67	416.67
Biomass electricity	312.50	625	312.50	416.67	416.67	416.67
PV electricity	0.17	0.34	---	0.23	0.23	0.23
Diesel electricity	0.17	0.34	0.17	0.23	0.23	0.23
Grid electricity	8.63	17.30	8.63	11.50	11.50	11.50

Iniyan *et al.*, (1998) conducted the Delphi study to determine the level of social acceptance. Two rounds of survey were conducted to arrive at consensus of opinion. Based on their analysis of survey, the social acceptance of various renewable energy systems for different end-uses sectors was determined. Social acceptance factor for solar, biomass/biogas, and commercial energy sources were estimated as 7.12, 10.49, and 74.49 respectively.

Next, the quantity of pollutants per weight of fuel can be accurately determined experimentally. The data describing stoichiometric composition of energy resources available in India is presented in Tables 4.7 (a & b).

Table 4.7a Stoichiometric Composition of Solid and Liquid Fuels (weight %)

Energy Resource	*Carbon (%)*	*Hydrogen (%)*	*Sulphur (%)*	*Nitrogen (%)*	*Oxygen (%)*	*Calorific Value (MJ/kg)*
Dung cake	33.40	3.90	0.07	0.90	---	11.76
Biomass	50.00	6.00	---	0.10	40.50	15.00
LPG	82.70	17.30	0.02	---	0.10	46.00
Kerosene	86.00	13.30	0.50	0.10	---	44.00
Diesel	87.00	10.70	1.20	0.10	---	42.33

Table 4.7b Stoichiometric Composition of Gaseous Fuels (volumetric %)

Energy Resource	*Methane (%)*	*Ethane (%)*	*Propane (%)*	*Carbon monoxide (%)*	*Carbon dioxide (%)*	*Hydrogen sulphide (%)*	*Nitrogen (%)*	*Oxygen (%)*	*Calorific Value (MJ/m^3)*
Natural gas	93.35	3.13	0.10	---	0.49	---	1.93	---	39.47
Biogas	50.10	---	---	0.90	35.8	7.2	---	6.00	20.14
Grid electricity (weightings) : Coal:65%, Oil:3%, Gas:1%	---	---	---	---	---	---	---	---	3.6

(Source: Ramanthan and Ganesh, 1993 and 1995)

Tables 4.8a to Table 4.8f shows, the emission rates of carbon oxides for different end-uses calculated by using following formula.

$$Carbon\ emissions = \frac{CarbonContent}{(CalorificValue)x(SystemEfficiency)} x3.6 \qquad kg/kWh$$

Similarly, emissions rates of sulphur oxides and nitrogen oxides for different energy resource end-use combinations are calculated and are shown in the same Tables 4.8a to Table 4.8f.

Table 4.8a Emission Rate (kg/kWh) From Various End-use Combination for Cooking End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Dung cake	0..6330	0.0013	1.7090
Biomass	0.7430	0.0000	0.1480
LPG	0.1798	0.00004	0.0000
Kerosene	0.2172	0.0013	0.0253
Biogas	0.1890	0.0418	0.0000
Solar thermal	0.0000	0.0000	0.0000
Biogas electricity	0.2954	0.0653	0.0000
Biomass electricity	0.3404	0.0000	0.0690
PV electricity	0.0000	0.0000	0.0000
Diesel electricity	0.3211	0.0044	0.0390
Grid electricity	0.3303	0.0016	0.4950

Table 4.8b Emission Rate (kg/kWh) From Various End-use Combination for Lighting End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Kerosene	9.7722	0.0569	1.1390
Biogas	9.4523	2.0909	0.0000
Biogas electricity	0.5908	0.1307	0.0000
Biomass electricity	0.6812	0.0000	0.1370
PV electricity	0.0000	0.0000	0.0000
Diesel electricity	0.6422	0.0089	0.0780
Grid electricity	0.6607	0.0032	0.9890

Table 4.8c Emission Rate (kg/kWh) From Various End-use Combination for Pumping End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Biogas electricity	0.2954	0.0653	0.0000
Biomass electricity	0.3404	0.0000	0.0690
Diesel electricity	0.3211	0.0044	0.0390
Grid electricity	0.3303	0.0016	0.4950

Table 4.8d Emission Rate (kg/kWh) From Various End-use Combination for Heating End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Dung cake	0..6330	0.0013	1.7090
Biomass	0.7430	0.0000	0.1480
Biogas	0.1890	0.0418	0.0000
Solar thermal	0.0000	0.0000	0.0000
Biogas electricity	0.3938	0.0871	0.0000
Biomass electricity	0.4538	0.0000	0.0910
PV electricity	0.0000	0.0000	0.0000
Diesel electricity	0.4281	0.0059	0.0520
Grid electricity	0.4404	0.0021	0.6590

Table 4.8e Emission Rate (kg/kWh) From Various End-use Combination for Cooling End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Biogas electricity	0.3938	0.0871	0.0000
Biomass electricity	0.4538	0.0000	0.0910
PV electricity	0.0000	0.0000	0.0000
Diesel electricity	0.4281	0.0059	0.0520
Grid electricity	0.4404	0.0021	0.6590

Table 4.8f Emission Rate (kg/kWh) From Various End-use Combination for Appliances End-use

Energy source	*Carbon (kg/kWh)*	*Sulphur (kg/kWh)*	*Nitrogen (10^{-2} kg/kWh)*
Biogas electricity	0.3938	0.0871	0.0000
Biomass electricity	0.4538	0.0000	0.0910
PV electricity	0.0000	0.0000	0.0000
Diesel electricity	0.4281	0.0059	0.0520
Grid electricity	0.4404	0.0021	0.6590

4.4 DEVELOPMENT AND SELECTION OF SCENARIO FOR IMPLEMENTATION

This section presents the results of energy resource allocation in *Panthadiya* village for the base year (i.e. 2004-05). Different scenarios are developed with the aim of identifying the feasible scenario for implementation. The selection of scenario is carried out on the basis of cost incurred in energy consumption, associated emissions, and use of local resources. The developed optimization model is solved using WINQSB software package. Six different scenarios were developed, with priorities for the objectives. Details of each scenario and the optimum allocations are discussed subsequently.

4.4.1 Present Energy Consumption Scenario

The present energy consumption scenario for the study village is shown in Table 4.9. It is observed that the study village is dependent on grid electricity for end-uses such as lighting, pumping, cooling and appliances. For thermal end-uses such as cooking and heating, mainly biomass and dung cakes are used. Heavy dependence on grid electricity is due to its present lower cost for the region and social acceptance of commercial energy systems. As shown in the Table 4.9, the end-use energy requirement and the cost of energy associated with present energy scenario is estimated as Rs. 5.38 millions at the present rates of costing and the associated emissions are 3829.05, 27.05 and 3.66 Tons/year for CO_x, NO_x and SO_x, respectively. The present energy consumption scenario is taken as a reference scenario for the purpose of comparison of projected scenarios in terms of associated total energy cost, maximum use of local resources, employment generation and emissions.

Table 4.9a Present Energy Resource Consumption Pattern for Various End-uses

Scenario	*End-uses*					
	Cooking	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Present energy consumption scenario	1. Dung cake (15%) 2. Biomass (70%) 3. LPG (15%)	Grid electricity (100%)	Grid electricity (100%)	1. Dung cake (20%) 2. Biomass (80%)	Grid electricity (100%)	Grid electricity (100%)

Table 4.9b Estimated End-use Energy Requirement for *Panthadiya* Village

End-use	*Energy requirement per person, per day, kWh*	*Annual energy requirement MWh/yr*
Cooking	1.495	0.895×10^3
Lighting	0.10	0.060×10^3
Pumping	---	$^{*}0.790 \times 10^3$
Heating	0.0002	0.120
Cooling	0.212	0.127×10^3
Appliances	0.055	0.033×10^3

**58 tube-well pumps of 12.5 hp used for 5 hours per day*

4.4.2 Optimizing Present Energy Consumption in *Panthadiya* Village

Optimal scenario is described in terms of goal values for individual objective functions by maximization or minimization. The goal value for an objective function is obtained by optimizing each objective function individually by linear programming technique.

Next, the multi-objective optimal scenario is obtained by optimizing all objective functions simultaneously by pre emptive goal programming method. In this method, weighting factors for individual objective function are determined. The weighting factor for an objective function is the difference between goal value for maximization (or minimization) and the goal obtained by minimization (or maximization) i.e. by reversal of optimization. The goal value obtained by reversal of optimization from maximization to minimization (or minimization to maximization) is called the worst value. The goal value, worst value and weighting factor for different objective functions are shown in Table 4.10.

Table 4.10 Goal Value, Worst Value and Weighting Factors for the Objectives

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	**1.215x10⁶**	Max	28.577x10⁶	**-27.362x10⁶**
Efficiency	Max	**0.575x10⁶**	Min	0.268x10⁶	**0.307x10⁶**
Reliability	Max	**1.805x10⁶**	Min	0.823 x10⁶	**0982x10⁶**
Local resources	Max	**1.905x10⁶**	Min	0	**1.905x10⁶**
Petroleum products	Min	**0**	Max	1.905x10⁶	**-1.905x10⁶**
Employment	Max	**1217.70**	Min	0.34	**1217.36**
Social acceptance	Max	**1.419x10⁶**	Min	0.162x10⁶	**1.257x10⁶**
Carbon emission	Min	**0.239x10⁶**	Max	1.474x10⁶	**-1.235x10⁶**
Sulphur emission	Min	**0**	Max	0.046x10⁶	**-0.046x10⁶**
Nitrogen emission	Min	**86.27**	Max	0.013x10⁶	**-0.013x10⁶**

Different scenarios are developed by assigning priority to all objective functions. Firstly, all objective functions were assigned equal priority. Next, the objective functions were grouped under the category such as economic, social-acceptance and emissions. The priority within and among the category is altered and scenarios are generated. These developed scenarios are compared with the present energy consumption scenario and scenario for implementation is recommended.

4.4.2.1 Scenario 1 – Equal Priority Scenario: The scenario is described in terms of optimal energy resource allocation to different end-uses with equal priority to all objective functions. The optimal energy resource allocation pattern is shown in Table 4.11 and Figure 4.2.

Table 4.11 Energy Resource Allocation Pattern for Various End-uses in Scenario 1

	End-uses					
Objective Function	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
No priority scenario	1. Biomass (30.00%) 2. LPG (37.65%) 3. Solar Thermal (20%) 4. PV electricity (12.35%)	PV electricity (100%)	Biomass electricity (100%)	Solar Thermal (100%)	PV electricity (100%)	PV electricity (100%)

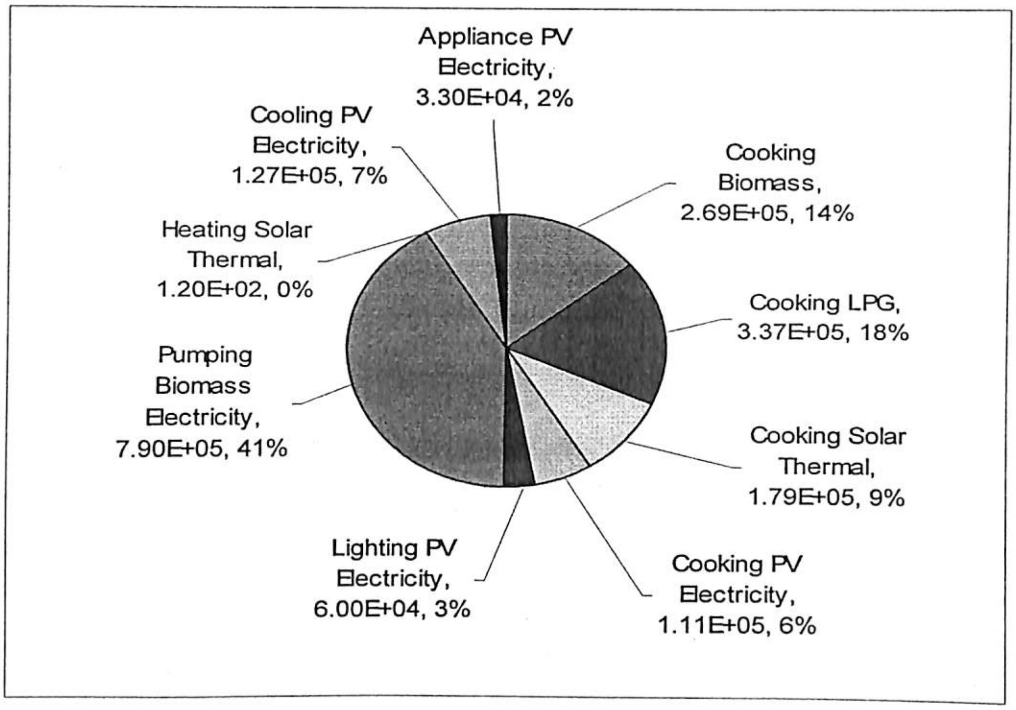

Figure 4.2 Energy Resource Allocation Pattern for Various End-uses in Scenario 1

The results of optimization with equal priority to objective functions show that, use of biomass, LPG, solar thermal and PV electricity should be promoted for meeting present cooking energy needs, PV electricity for meeting lighting, cooling and appliance energy needs, biomass electricity for pumping energy needs, and solar thermal for heating energy needs. Energy resource allocation in scenario 1 also show that biomass can meet 30.00%, LPG can meet 37.65% and PV electricity can met 12.35% of total cooking energy requirement. Similarly, PV electricity can meet 100% of lighting, cooling and appliance end-use requirement.

The cost associated with scenario 1 is estimated to be Rs. 13.16 millions and the associated emissions are 1630.82, 3.02, 0.02 Tons/year for CO_x, NO_x and SO_x, respectively. The comparison of cost and emissions associated with equal priority scenario and present energy scenario is shown in Table 4.12.

Table 4.12 Comparison of Cost and Emissions for Present Energy Consumption Scenario and Energy Scenario1

Scenario	*Cost associated, million Rs/year*	*Emissions associated*		
		COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario	5.38	3829.05	3.66	27.05
Optimal Scenario	13.16	1630.82	0.02	3.02

The comparison shows that the cost associated with equal priority scenario is almost two and half times the present cost of energy consumption. However, the associated emissions are reduced. The selection of energy scenario ought to be guided by the cost to be incurred, and also by the avenues offered for higher employment generation, increase in use of local resources, and decrease in associated emissions. The cost associated with the allocation scenario will primarily decide its implementability therefore scenario 1 should not be promoted for implementation.

Therefore, different scenarios are generated by selectively assigning priority to objective functions for reducing the associated cost, increasing employment generation, increasing local resource utilization and reduction in associated emissions.

4.4.2.2 Scenario 2 – Priority Scenario: In this scenario, the objective functions are divided into three categories: economic, security-acceptance and environmental. Under economic objectives cost of energy, system efficiency, reliability of energy system, and employment generation are considered; while under security-acceptance, minimization of imported petroleum products, maximization of local resources and social acceptance are considered. The environment related objectives include the minimization of CO_x, SO_x and NO_x.

In this scenario, the priority of environment emissions is varied from one to three and the economic objectives have always given higher priority as compared to security-acceptance objectives. The priorities are shown in Table 4.13 and the results of energy resource allocation are shown in Table 4.14.

Table 4.13 Priority of Objectives

Objectives	*Case 1*	*Case 2*	*Case 3*
Emissions	1	2	3
Economic	2	1	1
Security-acceptance	3	3	2

Table 4.14 Energy Resource Allocation Pattern for Scenario 2

	End-uses					
Scenario	***Cooking***	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Case 1	1. Dung cake (13.30%) 2. Biomass (48.83%) 3. PV electricity (37.87%)	PV electricity (100%)	Grid electricity (100%)	Solar thermal (100%)	PV electricity (100%)	PV electricity (100%)
Case 2	1. Biomass (27.60%) 2. Solar thermal (20.00%) 3. PV electricity (52.40%)	PV electricity (100%)	Grid electricity (100%)	Solar Thermal (100%)	PV electricity (100%)	PV electricity (100%)
Case 3	1. LPG (33.41%) 2. Solar Thermal (20%) 3. Biomass electricity (39.44%) 4. PV electricity (7.15%)	PV electricity (100%)	Biomass electricity (100%)	Solar Thermal (100%)	PV electricity (100%)	Biomass electricity (100%)

Case 1: The results of optimization show that when environment objectives are given higher priority, PV electricity should be promoted for lighting, cooling and appliance end-uses since the energy source is emission free. There are no constraints on the availability of the solar energy in the village, since it is available most of the time during a year and is observed to be available for more than 270 days in a year. The results of analysis show that grid electricity is only to be preferred for pumping end-use from the point of view of present subsidized prices.

Case 2: The results are almost similar as observed case 1 except the allocation of dung cake for cooking end-use. In this case biomass energy share in cooking energy requirement is reduced from 48.83% to 27.60%. Solar thermal and PV electricity is also allocated for cooking end-use due to decrease in the environmental priority from one to two.

Case 3 The results of optimization when economic objectives are given higher priority than security-acceptance and environment objectives show that large portion of LPG (33.41%) and biomass electricity (39.44%) is to be promoted for cooking. The results of optimization show that PV electricity (7.15%) should also be allocated for cooking end-use. Solar thermal with its low cost, will meet 20% of the cooking energy requirement, and total heating energy requirement. Biomass electricity should be promoted for pumping, cooling and appliance end-uses and PV electricity for cooling end-use due to increase in priority to social-acceptance objectives.

The cost and emissions associated with achieving energy scenario 2 are shown in Table.

Table 4.15 Comparison of Cost and Emission for Present Energy Consumption Scenario and Scenario 2

Scenario		*Cost associated, million Rs/year*	*Emissions associated*		
			COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario		5.38	3829.05	3.66	27.05
Scenario 1	***Case 1***	15.43	2679.47	2.49	20.67
	Case 2	16.91	1405.79	1.58	7.04
	Case 3	11.43	618.83	0.02	1.04

The comparison of cost associated in present energy consumption scenario and scenario 2 show that the associated cost increases by many folds, when environment emissions are given a priority. If the security-acceptance objectives are given higher priority, it also results in higher cost than present energy consumption scenario. Therefore, these scenarios should be preferred only when the reduction in environment emissions is the priority.

Different scenarios are developed for reducing associated cost by assigning the priority of economic objectives as discussed in scenario 3.

4.4.2.3 Scenario 3 – Economic Objective Scenario: In this scenario, changes are made within the priorities of economic objectives. Priority to cost objective function is varied from one to three, and the employment generation is always given higher priority as compared to efficiency and reliability. In this scenario, the other objective-functions have given lowest priority. The chosen priorities are shown in Table 4.16 and the results of energy resource allocation are shown in Table 4.17.

Table 4.16 Priorities to Economic Objectives

Objective	*Case 1*	*Case 2*	*Case 3*
Cost	1	2	3
Employment generation	2	1	1
Efficiency	3	3	2
Reliability	3	3	2

Table 4.17 Energy Resource Allocation Pattern for Scenario 3

	End-uses					
Scenario	***Cooking***	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Case 1	1. Biomass (6.59%) 2. Solar Thermal (20%) 3. Biomass electricity (73.41%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)
Case 2	1. Solar thermal (20%) 2. Biomass electricity (80%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)
Case 3	1. Solar Thermal (20%) 2. Biomass electricity (80.00%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Case 1: The results of optimization when energy cost is assigned the highest priority show that biomass and biomass electricity for cooking; and solar thermal for cooking and heating should be preferred, due to their low cost and higher potential for employment. Biomass electricity is to be promoted for lighting, cooling and appliance end-uses due to its low cost (Rs. 2.50/kWh) compared with other energy resources. Biomass electricity should be promoted for pumping end-use due the lower costs as Rs. 2.50/kWh and is local energy resource.

Case 2: The results of optimization when employment generation is assigned the higher priority than cost, results in the almost same energy resources allocation for the end-uses, except the use of biomass electricity for cooking in place of biomass. Therefore, a decrease in the priority of the cost function from one to two does not change the energy resource allocation.

Case 3: The results of optimization when employment generation is assigned the highest priority and cost is given the lower priority, as in case 3 show the similar energy resources allocation as observed in case 2. The biomass electricity is to be allocated for different end-uses, due to high employment potential in bio-energy resources at the lesser cost. Therefore, a decrease in the priority of the cost function from one to three does not change the energy resource allocation.

The cost and emissions associated with achieving energy scenario 3 are shown in Table 4.18.

Table 4.18 Comparison of Cost and Emissions for Present Energy Consumption Scenario and Scenario3

Scenario		*Cost associated, million Rs/year*	*Emissions associated*		
			COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario		**5.38**	**3829.05**	**3.66**	**27.05**
Scenario 1	***Case 1***	5.89	1096.68	---	2.21
	Case 2	5.83	864.00	---	1.75
	Case 3	5.83	864.00	---	1.75

The comparison of costs associated with present energy consumption scenario and scenario 3, show that the cost and environmental emissions are reduced for all the cases. In all the cases, biomass electricity is to be promoted for lighting, pumping, cooling and appliance end-uses, which is due to availability of biomass in the village. Therefore, case 2 scenario should be preferred for implementation which will have higher employment generation potential due to the use of local available resources at the optimal cost.

When the employment generation is assigned higher priority than reliability and efficiency of energy system, the cost associated in achieving the scenario 3 increases as compared to present energy consumption scenario. Therefore, this scenario should only be preferred when the employment generation is the priority.

Next, different scenarios are developed by assigning the priority to security-acceptance objectives to find acceptable scenario at the lower cost and higher employment generation options as discussed in scenario 4.

4.4.2.4 Scenario 4 – Security-Acceptance Scenario: In this scenario, the security-acceptance objectives functions are assigned higher priorities and other objective-functions are the lower priority. The chosen priorities are shown in Table 4.19 and the results of energy resource allocation are shown in Table 4.20.

Table 4.19 Priorities for Security-Acceptance Objectives

Objectives	*Case 1*	*Case 2*	*Case 3*
Petroleum products	1	2	3
Local resources	2	1	2
Social acceptance	3	3	1

Table 4.20 Energy Resource Allocation Pattern for Scenario 4

	End-uses					
Objective Function	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Case 1	1. Biomass (22.24%) 2. LPG (57.76%) 3. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

	End-uses					
Objective Function	***Cooking***	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Case 2	1. Biomass (22.24%) 2. LPG (57.76%) 3. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)
Case 3	1. Biomass (22.24%) 2. LPG (18.10%) 3. Biogas (39.66%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization in case 1 and case 2 show that LPG and solar thermal is to be promoted for cooking energy requirements, since minimum use of petroleum products lead to maximum use of local resources. All the cases result in almost similar energy resources allocation pattern for the end-uses except the use of biomass and biogas for cooking end-use. Therefore, increase in the priority of the social acceptance factor from three to one does not cause change the energy resource allocation.

The cost and emissions associated with achieving energy scenario 4 are shown in Table 4.21.

Table 4.21 Comparison of Cost and Emission for Present Energy Consumption Scenario and Scenario 4

Scenario		*Cost associated, million Rs/year*	*Emissions associated*		
			COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario		5.38	3829.05	3.66	27.05
Scenario 1	*Case 1*	6.20	1615.20	0.04	2.86
	Case 2	6.20	1615.20	0.04	2.86
	Case 3	5.17	1621.72	29.68	2.86

The comparison of present energy consumption scenario and scenario 4 shows that the cost associated in the cases 1 and 2 are higher than in reference scenario i.e. present energy consumption scenario, and the associated emissions are reduced. Therefore, these scenarios should only be preferred when the maximum use of local resources is the objective. The results of optimization when social acceptance and use of local resources objective is given a higher priority than use of petroleum products objective show the reduction in associated cost and environment emissions. It can be seen that the SOx emissions increases from 3.66 to 29.68 Tons/year due to the allocation of biogas for cooking. Therefore, case 3 of security-acceptance scenario should only be preferred when the social acceptance and use of local resources is the priority. Different scenarios are developed by assigning higher priority to cost and employment generation to find acceptable scenario at the lower cost and higher employment generation options as discussed in scenario 5.

4.4.2.5. Scenario 5 - Cost-Employment Generation Scenario: In this scenario, cost and employment generation objective functions are assigned a higher priority as compared to other objective functions. This scenario is important, where the objective of energy resource allocation is socio-economic development. The results of energy resource allocation are shown in Table 4.22.

Table 4.22 Energy Resource Allocation Pattern for Prioritized Cost and Employment Generation Factor

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Case I	1. Biomass (17.32%) 2. LPG (22.96%) 3. Biogas (39.72%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (22.96%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs.

The cost and emissions associated with achieving energy scenario 5 are shown in Table 4.23.

Table 4.23 Comparison of Cost and Emission for Present Energy Consumption Scenario and Scenario 5

Scenario	*Cost associated, million Rs/year*	*Emissions associated*		
		COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario	**5.38**	**3829.05**	**3.66**	**27.05**
Scenario 4	5.06	1445.11	29.74	2.48

The comparison of present energy consumption scenario and scenario 5 shows that the cost associated is lower than the present cost of utilization, and the associated emissions are reduced. Therefore, this scenario should be preferred only when the maximum use of local resources and employment generation are the objectives.

4.4.2.6. Scenario 6 – Efficiency Scenario:

Case 1: In this scenario, the maximization of system efficiency is assigned the first priority and the other objective functions are priority of two. The results of energy resource allocation are shown in Table 4.24.

Table 4.24 Energy Resource Allocation Pattern for case 1 of Scenario 6

	End-uses					
Objective Function	***Cooking***	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Case 1	1. Biomass (17.32%) 2. LPG (22.96%) 3. Biogas (39.72%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	1. Biomass electricity (100%)

The results of optimization resulted in similar results as observed in scenario 5 and show that biomass electricity is to be promoted for lighting, pumping, cooling and appliance end-uses. The energy allocation is due to the system efficiency of 21.89%. Biomass and biogas for cooking, and solar thermal for cooking and heating is to be allocated due to their resource availability and associated system efficiency of 16.15%, 44% and 40% respectively.

Case 2: In this case, increase of 25% is assumed for all renewable energy sources. The optimization problem is solved for new values of system efficiency. The optimization results for energy resource allocation are shown in Table 4.25.

Table 4.25 Energy Resource Allocation Pattern for 25% Increase in System Efficiency for Renewable Energy Sources

Scenario	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
No priority scenario with increase in system efficiency of 25% for renewable energy sources	1. Biomass (17.32%) 2. LPG (22.96%) 3. Biogas (39.72%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization for case 2 show that even though 25% increase in system efficiency of renewable energy sources, do not change the energy resource allocations as observed case 1. Thus, the solution is found to be not sensitive to 25% increase in the system efficiency.

The cost and emissions associated with achieving energy scenario 6 are shown in Table 4.26.

Table 4.26 Comparison of Cost and Emission for Present Energy Consumption Scenario and Scenario 6

Scenario		*Cost associated, million Rs/year*	*Emissions associated*		
			COx, Tons/year	*SOx, Tons/year*	*NOx, Tons/year*
Present Scenario		**5.38**	**3829.05**	**3.66**	**27.05**
Scenario 1	***Case 1***	5.06	1445.11	29.74	2.48
	Case 2	5.06	1445.11	29.74	2.48

The comparison of present energy consumption scenario and scenario 6 shows that the cost and emissions associated, in all the cases is still higher than the present cost of utilization. Therefore, these scenarios should not be preferred for implementation.

Present energy resource allocation for *Panthadiya* village is presented. It is observed that present cost of energy consumption can be reduced by implementing case 3 of scenario 4 or by implementing scenario 5 or scenario 6. Out of these scenarios, scenario 5 is to be implemented due the use of biogas and solar thermal for cooking, which is local source of energy. Scenario 5 show that, biomass electricity should be promoted for lighting, pumping, cooling and appliance end-uses; biogas and LPG for cooking; solar thermal for cooking and heating end-uses. This scenario results in cost reduction of 5.95% of present cost of energy and reduction of 62.26% and 90.83% in CO_x, and NO_x, respectively but will increase SO_x emissions by 87.69%. Due to the use of local energy resources, this scenario will satisfy the goal of employment generation and the reduction of environment emissions.

The results show that complete implementation of scenario 5 in *Panthadiya* village, will leave sizable energy resource unutilized, for the base year 2004-05. The unutilized energy resource is shown in Table 4.27, which suggests that the resource may be utilized in the nearby villages for studying the inter village-mix energy utilization.

Table 4.27 Estimated Unutilized Energy Resources in Scenario 5 for *Panthadiya* Village

Name of the Village	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Panthadiya	5.61×10^6	5.61×10^6	9.26×10^6	0.93×10^6

The results obtained as above, suggests that new definition of region for planning may be evolved, so as to satisfy short and medium term energy requirements of the region so defined, which is discussed in next chapter.

Chapter 5: Region Dependent Development of IRES

In this chapter, suitability of region for development of Integrated Renewable Energy System IRES is discussed. The methodology adopted for identifying the region for IRES is developed and shown in Figure 5.1. The surveyed villages of Jhunjhunu district of Rajasthan are considered for the study. A detailed discussion on energy resource allocation in neighbouring villages of study village, *Panthadiya*, namely *Bisanpura* 1^{st}, *Bisanpura* 2^{nd}, and *Morva* is presented. This is followed by inter village-mix with the present energy needs in view of identifying region for energy planning is demonstrated. Energy allocation scenarios are generated for the region defined in view of known short and medium term objectives. For short term objectives of energy planning, typically plans are developed for achieving objectives of minimum cost of energy utilization, maximum employment generation, and maximum use of local resources.

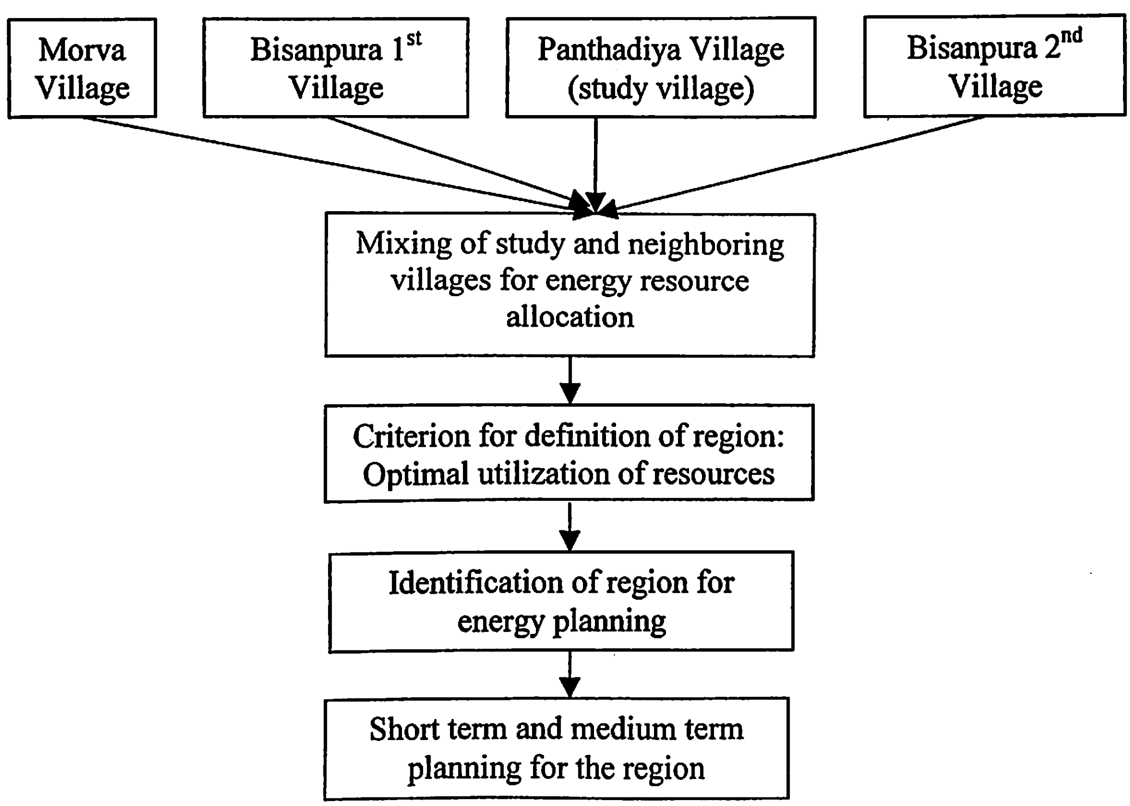

Figure 5.1 Methodology Adopted for Defining the Region for IRES Development

In medium term energy planning, typically plans are developed for achieving objectives of minimum cost of energy utilization, maximum employment generation, maximum use of local resources and minimum environment emissions. The developed short and medium term scenarios are compared and optimal scenario is suggested for implementation.

5.1 ENERGY RESOURCE ALLOCATION IN NEIGHBOURING VILLAGES

Energy resource allocation is important in IRES design and development. The energy resource allocation for the *Panthadiya* village (study village) is discussed in Chapter 4. There it is shown that the present cost of energy consumption and emissions can be reduced by implementing Scenario 5. In scenario 5, cost and employment generation objective functions were chosen and assigned higher priority than that for other objective functions such as efficiency of the system, reliability of the source, use of local resources, use of petroleum products, social acceptance and environment emissions. The type of scenario is useful, when objective of energy resource allocation is socio-economic development (Laxmi *et al.* 2003). Scenario 5 was shown to achieve the goal of employment generation at reduced levels of environment emissions due to the use of local energy resources for different end-uses. In scenario 5, the unutilized energy resource is shown in Table 5.1.

Table 5.1 Estimated Unutilized Energy Resources in Scenario 5 for *Panthadiya* Village

Name of the Village	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Panthadiya	5.61×10^6	5.61×10^6	9.26×10^6	0.93×10^6

It is observed from Table 5.1 that 10.04% of biomass energy is unutilized in scenario 5 and dung cake energy is not allocated in present energy resource allocation. Thus, unutilized biomass and dung cake energy is available for allocating to neighboring villages to identify region for fast track development of IRES. To allocate the unutilized energy resource of *Panthadiya* village, present energy resource allocation is carried out in neighboring villages. Energy resource allocation is carried out by assigning higher priority to cost and employment generation objective functions higher than that for other objective functions to estimate unutilized energy resource in optimal scenario. The results of optimal energy resource allocation in neighboring villages are discussed subsequently.

5.1.1 Optimal Energy Resource Allocation in Neighboring Villages

The methodology adopted for energy resource allocation is the same as discussed in Chapter 4. The optimal energy scenarios are generated for *Bisanpura 1st*, *Bisanpura 2nd* and *Morva* villages. The estimated end-use energy requirements of the villages are shown in Table 5.2.

Table 5.2 Estimated End-use Energy Requirement for Neighboring Villages

End-use	*Energy requirement per person, per day, kWh for Bisanpura 1st*	*Annual energy requirement MWh/yr for Bisanpura 1st*	*Energy requirement per person, per day, kWh for Bisanpura 2nd*	*Annual energy requirement MWh/yr for Bisanpura 2nd*	*Energy requirement per person, per day, kWh for Morva*	*Annual energy requirement MWh/yr for Morva*
Cooking	1.499	0.381 x 10^3	1.463	0.394 x 10^3	1.455	1.409 x 10^3
Lighting	0.14	0.036 x 10^3	0.12	0.032 x 10^3	0.11	0.107 x 10^3
Pumping	---	0.286 x 10^3	---	0.327 x 10^3	---	0.980 x 10^3
Heating	0.0002	0.051	0.0002	0.054	0.0002	0.194
Cooling	0.344	0.088 x 10^3	0.274	0.074 10^3	0.207	0.200 x 10^3
Appliances	0.082	0.021 x 10^3	0.061	0.016x 10^3	0.052	0.050 x 10^3

It can be observed that in all the villages, cooking end-use contributes for maximum followed by pumping end-use, cooling end-use, lighting end-use, appliance end-use, and heating end-use to total energy requirement of the village.

Also, the estimated biomass, dung cake and biogas energy resource availability in neighboring villages are shown in Table 5.3. It can be seen that number of cattle to population ratio is 0.59 and 0.52, which is higher than the ratio observed in *Panthadiya* village (0.50), due to which the biogas energy potential is higher in *Bisanpura 1st* and *Bisanpura 2nd* villages. It can be noted that the number of cattle to population ratio is 0.43, which is lower than the ratio observed in *Panthadiya* village (0.50), due to which the biogas energy potential is lower in the *Morva* village.

Table 5.3 Estimated Biomass, Dung cake, Biogas Energy Potential in Neighboring Villages

Name of the Village	*Population*	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake consumption, MJ/year*	*Biogas availability, MJ/year*
Bisanpura 1st	697	169	3.26×10^6	389	2.67×10^6	1.22×10^6
Bisanpura 2nd	737	167	3.21×10^6	384	2.63×10^6	1.20×10^6
Morva	2652	733	14.10×10^6	1149	7.86×10^6	3.59×10^6

Optimal energy scenario is described in terms of goal values for individual objective functions by maximization or minimization. The goal value for an objective function is obtained by optimizing each objective function individually by linear programming technique. Next, the multi-objective optimal energy scenario is obtained by optimizing all objective functions simultaneously by pre emptive goal programming method as discussed in Chapter 4. The goal value, worst value and weighting factor for different objective functions for neighboring villages are shown in Tables 5.4a to 5.4c. The negative value for weighting factor indicates that the energy sources are available to satisfy the defined objective, as can be observed in Tables 5.4a to 5.4c. The goal value for such functions is also observed to be zero.

Table 5.4a Goal Value, Worst Value and Weighting Factors for the Objectives in *Bisanpura 1st* Village

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	0.541 x 10^6	Max	12.181 x 10^6	-11.640 x 10^6
Efficiency	Max	0.243 x 10^6	Min	0.108 x 10^6	0.135 x 10^6
Reliability	Max	0.769 x 10^6	Min	0.310 x 10^6	0.459 x 10^6
Local resources	Max	0.812 x 10^6	Min	0	0.812 x 10^6
Petroleum products	Min	0	Max	0.812 x 10^6	-0.812 x 10^6
Employment	Max	500.15	Min	0.15	500.00
Social acceptance	Max	0.605 x 10^6	Min	0.068 x 10^6	0.537 x 10^6
Carbon emission	Min	0.085 x 10^6	Max	0.722 x 10^6	-0.637 x 10^6
Sulphur emission	Min	0	Max	0.022 x 10^6	-0.022 x 10^6
Nitrogen emission	Min	5.77	Max	0.005 x 10^6	-0.005 x 10^6

Table 5.4b Goal Value, Worst Value and Weighting Factors for the Objectives in *Bisanpura 2nd* Village

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	0.548 x 10^6	Max	12.646 x 10^6	-12.098 x 10^6
Efficiency	Max	0.253 x 10^6	Min	0.116 x 10^6	0.137 x 10^6
Reliability	Max	0.798 x 10^6	Min	0.346 x 10^6	0.452 x 10^6
Local resources	Max	0.843 x 10^6	Min	0	0.843 x 10^6
Petroleum products	Min	0	Max	0.843 x 10^6	-0.843 x 10^6
Employment	Max	492.98	Min	0.15	492.83
Social acceptance	Max	0.628 x 10^6	Min	0.071 x 10^6	0.557 x 10^6
Carbon emission	Min	0.098 x 10^6	Max	0.691 x 10^6	-0.593 x 10^6
Sulphur emission	Min	0	Max	0.022 x 10^6	-0.022 x 10^6
Nitrogen emission	Min	23.32	Max	0.006 x 10^6	-0.006 x 10^6

Table 5.4c Goal Value, Worst Value and Weighting Factors for the Objectives in *Morva* Village

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**1.769 x 10^6**	Max	41.193 x 10^6	**-39.424 x 10^6**
Efficiency	**Max**	**0.841 x 10^6**	Min	0.373 x 10^6	**0.468 x 10^6**
Reliability	**Max**	**2.613 x 10^6**	Min	1.059 x 10^6	**1.554 x 10^6**
Local resources	**Max**	**2.746 x 10^6**	Min	0	**2.746 x 10^6**
Petroleum products	**Min**	**0**	Max	2.746 x 10^6	**-2.746 x 10^6**
Employment	**Max**	**1785.68**	Min	0.50	**1785.18**
Social acceptance	**Max**	**2.046 x 10^6**	Min	0.229 x 10^6	**1.817 x 10^6**
Carbon emission	**Min**	**0.294 x 10^6**	Max	2.332 x 10^6	**-2.038 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.067 x 10^6	**-0.067 x 10^6**
Nitrogen emission	**Min**	**71.14**	Max	0.019 x 10^6	**-0.019 x 10^6**

Optimal Scenario for Implementation: In this scenario, cost and employment generation objective functions are assigned a higher priority as compared to other objective functions. This scenario is important, from the view point of socio-economic development of the villages. The results of energy resource allocation are shown in Tables 5.5a to 5.5c.

Table 5.5a Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Bisanpura 1st* Village

Objective Function	*End-uses*					
	Cooking	***Lighting***	***Pumping***	***Heating***	***Cooling***	***Appliances***
Optimal Scenario	1. Biomass (6.09%) 2. LPG (29.42%) 3. Biogas (44.49%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.5b Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Bisanpura* 2^{nd} Village

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario	1. Biomass (3.75%) 2. LPG (33.86%) 3. Biogas (42.39%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.5c Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Morva* Village

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Case 1	1. Biomass (18.91%) 2. LPG (25.71%) 3. Biogas (35.38%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization for neighboring villages show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (29.425% in *Bisanpura* 1^{st}, 33.86 in *Bisanpura* 2^{nd} and 25.71% in *Morva* village) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs in all the neighboring villages.

The cost associated with optimal scenario for *Bisanpura 1st* village is Rs. 2.18 millions and the associated emissions are 471.23, 0.738, 14.18 Tons/year for CO_X , NO_X and SO_X, respectively. The cost associated with optimal scenario for *Bisanpura 2nd* village is Rs. 2.24 millions and the associated emissions are 437.39, 0.66, 13.97 Tons/year for CO_X , NO_X and SO_X, respectively. The cost associated with optimal scenario for *Morva* village is Rs. 7.51 millions and the associated emissions are 2271.52, 3.91, 41.71 Tons/year for CO_X , NO_X and SO_X, respectively.

Table 5.6 shows the unutilized energy resource in implementing optimal scenario for neighboring villages in the base year (2005-06).

Table 5.6 Estimated Unutilized Energy Resources in Optimal Scenario for Neighboring Villages

Name of the Village	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Bisanpura 1st	2.67×10^6	2.67×10^6	3.26×10^6	0.50×10^6
Bisanpura 2nd	2.63×10^6	2.63×10^6	3.21×10^6	0.60×10^6
Morva	7.86×10^6	7.86×10^6	14.10×10^6	1.58×10^6

It can be observed that in *Bisanpura 1st* village the dung cake (100%) and biomass energy resource (15.34%) is not utilized in optimal scenario. In Bisanpura 2nd village, the dung cake (100%) and biomass energy resource (18.69%) is not utilized in optimal scenario. In Morva village dung cake (100%) and biomass energy resource (11.21%) is not utilized in optimal scenario. Therefore, *Bisanpura 1st*, *Bisanpura 2nd* and *Morva* village is considered to study inter village energy mix with *Panthadiya* village.

5.2 INTER VILLAGE-MIX FOR IRES DEVELOPMENT

Renewable energy utilization for electricity generation has been growing during the past twenty-five years, transforming renewable potential to actual energy production and increasing their share in the energy supply. Moreover, because of their decentralized nature, renewable energy applications have a considerable potential in rural areas. As local resources, they offer prospects for sustainable job creation, social cohesion and regional development.

The region-wise development of IRES, involves identification of region, assessment of existing demand and future demand projections, and evaluation of present and future resource availability, engineering and technical feasibility and reliability, economic attractiveness of systems. The region for IRES design can be nation, state, district, block or village. In the present research work, the region is defined for micro-level energy planning with respect to optimal energy resource utilization among the villages. Therefore, inter village-mix of energy sources and an energy requirement is considered for determining dependence of scenario for IRES development.

5.2.1 Optimal Energy Resource Allocation in Inter Village-mix

The methodology adopted for energy resource allocation is the same as discussed in Chapter 4. The optimal energy scenarios are generated for *Panthadiya-Bisanpura 1st* (P-B1), *Panthadiya-Bisanpura 2nd* (P-B2), *Panthadiya-Morva* (P-M), *Panthadiya-Bisanpura 1st-Bisanpura 2nd* (P-B1-B2), *Panthadiya-Bisanpura 1st-Morva* (P-B1-M), *Panthadiya-Bisanpura 2nd-Morva* (P-B2-M), *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* (P-B1-B2-M) villages. Table 5.7 shows the estimated end-use energy requirement of these villages.

Table 5.7 Estimated End-use Energy Requirement for Village-mix

End-use	*Annual energy requirement MWh/yr for P-B1 village*	*Annual energy requirement MWh/yr for P-B2 village*	*Annual energy requirement MWh/yr for P-M village*	*Annual energy requirement MWh/yr for P-B1-B2 village*	*Annual energy requirement MWh/yr for P-B1-M village*	*Annual energy requirement MWh/yr for P-B2-M village*	*Annual energy requirement MWh/yr for P-B1-B2-M village*
Cooking	1.276×10^3	1.289×10^3	2.304×10^3	1.670×10^3	2.685×10^3	2.698×10^3	3.079×10^3
Lighting	0.096×10^3	0.092×10^3	0.167×10^3	0.128×10^3	0.203×10^3	0.199×10^3	0.235×10^3
Pumping	1.076×10^3	1.117×10^3	1.77×10^3	1.403×10^3	2.056×10^3	2.097×10^3	2.383×10^3
Heating	0.171	0.174	0.314	0.225	0.365	0.368	0.419
Cooling	0.215×10^3	0.201×10^3	0.327×10^3	0.289×10^3	0.415×10^3	0.401×10^3	0.489×10^3
Appliances	0.054×10^3	0.049×10^3	0.083×10^3	0.070×10^3	0.104×10^3	0.099×10^3	0.120×10^3

It can be observed that in all the village-mix energy end-use is maximum for cooking followed by pumping, cooling, lighting, appliance, and heating of total energy requirement of the village-mix.

Table 5.8 shows the estimated biomass, dung cake and biogas availability in *Panthadiya-Bisanpura 1st*, *Panthadiya-Bisanpura 2nd*, *Panthadiya-Morva*, *Panthadiya-Bisanpura 1st-Morva*, *Panthadiya-Bisanpura 2nd-Morva*, *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* village-mix.

It can be seen that number of cattle to population ratio is 0.52 and 0.51 in *Panthadiya-Bisanpura 1st* and *Panthadiya-Bisanpura 2nd* village-mix, which is higher than the ratio observed in *Panthadiya* village (0.50). As a result, biogas energy potential is higher in village mix of *Panthadiya-Bisanpura 1st* and *Panthadiya-Bisanpura 2nd* villages. It is to be noted that the number of cattle to population ratio is 0.46, which is lower than the ratio observed in *Panthadiya* village (0.50). As a result, the biogas energy potential is lower in the *Panthadiya-Morva* village mix.

Table 5.8 Estimated Biomass, Dung cake, Biogas Energy Potential in Neighboring Village-mix

Name of the Village-mix	*Population*	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake consumption, MJ/year*	*Biogas availability, MJ/year*
Panthadiya-Bisanpura 1^st^	2337	650	12.52×10^6	1209	8.28×10^6	3.78×10^6
Panthadiya-Bisanpura 2^nd^	2377	648	12.47×10^6	1204	8.24×10^6	3.76×10^6
Panthadiya-Morva	4292	1214	23.36×10^6	1969	13.47×10^6	6.15×10^6
Panthadiya-Bisanpura 1^st^-Bisanpura 2^nd^	3074	817	15.73×10^6	1593	10.91×10^6	4.98×10^6
Panthadiya-Bisanpura 1^st^-Morva	4989	1383	26.62×10^6	2358	16.14×10^6	7.37×10^6
Panthadiya-Bisanpura 2^nd^-Morva	5029	1381	26.57×10^6	2353	16.10×10^6	7.35×10^6
Panthadiya-Bisanpura 1^st^-Bisanpura 2^nd^-Morva	5726	1550	29.83×10^6	2742	18.77×10^6	8.57×10^6

The multi-objective optimization is achieved for estimated end-use energy requirements and resource availability in the village. The goal value, worst value and weighting factor for different objective functions in *Panthadiya-Bisanpura 1^st^*, *Panthadiya-Bisanpura 2^nd^* and *Panthadiya-Morva* villages are shown in Tables 5.9a to 5.9g. It can be observed that the goal value, worst value have liner relationship with the energy requirements. The maximum goal value is observed to be 4.073×10^6 for the cost objective function, when all the villages are considered.

Table 5.9a Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura* 1^{st} Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	**1.756 x 10⁶**	Max	40.758 x 10⁶	**-39.002 x 10⁶**
Efficiency	Max	**0.818 x 10⁶**	Min	0.376 x 10⁶	**0.442 x 10⁶**
Reliability	Max	**2.574 x 10⁶**	Min	1.133 x 10⁶	**1.441 x 10⁶**
Local resources	Max	**2.717 x 10⁶**	Min	0	**2.717 x 10⁶**
Petroleum products	Min	**0**	Max	2.717 x 10⁶	**-2.717 x 10⁶**
Employment	Max	**1718.34**	Min	0.49	**1717.85**
Social acceptance	Max	**2.024 x 10⁶**	Min	0.229 x 10⁶	**1.795 x 10⁶**
Carbon emission	Min	**0.324 x 10⁶**	Max	2.196 x 10⁶	**-1.872 x 10⁶**
Sulphur emission	Min	**0**	Max	0.069 x 10⁶	**-0.069 x 10⁶**
Nitrogen emission	Min	**92.04**	Max	0.019 x 10⁶	**-0.019 x 10⁶**

Table 5.9b Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura* 2^{nd} Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	**1.764 x 10⁶**	Max	41.223 x 10⁶	**-39.459 x 10⁶**
Efficiency	Max	**0.828 x 10⁶**	Min	0.383 x 10⁶	**0.445 x 10⁶**
Reliability	Max	**2.603 x 10⁶**	Min	1.168 x 10⁶	**1.435 x 10⁶**
Local resources	Max	**2.748 x 10⁶**	Min	0	**2.748 x 10⁶**
Petroleum products	Min	**0**	Max	2.748 x 10⁶	**-2.748 x 10⁶**
Employment	Max	**1708.72**	Min	0.50	**1708.22**
Social acceptance	Max	**2.047 x 10⁶**	Min	0.233 x 10⁶	**1.814 x 10⁶**
Carbon emission	Min	**0.337 x 10⁶**	Max	2.165 x 10⁶	**-1.828 x 10⁶**
Sulphur emission	Min	**0**	Max	0.068 x 10⁶	**-0.068 x 10⁶**
Nitrogen emission	Min	**111.15**	Max	0.019 x 10⁶	**-0.019 x 10⁶**

Table 5.9c Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Morva* Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**2.983 x 10^6**	Max	69.769 x 10^6	**-66.786 x 10^6**
Efficiency	**Max**	**1.416 x 10^6**	Min	0.640 x 10^6	**0.776 x 10^6**
Reliability	**Max**	**4.418 x 10^6**	Min	1.881 x 10^6	**2.537 x 10^6**
Local resources	**Max**	**4.651 x 10^6**	Min	0	**4.651 x 10^6**
Petroleum products	**Min**	**0**	Max	4.651 x 10^6	**-4.651 x 10^6**
Employment	**Max**	**3004.36**	Min	0.84	**3003.52**
Social acceptance	**Max**	**3.465 x 10^6**	Min	0.391 x 10^6	**3.074 x 10^6**
Carbon emission	**Min**	**0.533 x 10^6**	Max	3.807 x 10^6	**-3.274 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.113 x 10^6	**-0.113 x 10^6**
Nitrogen emission	**Min**	**156.78**	Max	0.033 x 10^6	**-0.033 x 10^6**

Table 5.9d Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura 1st-Bisanpura 2nd* Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**2.305 x 10^6**	Max	53.403 x 10^6	**-51.098 x 10^6**
Efficiency	**Max**	**1.071 x 10^6**	Min	0.492 x 10^6	**0.579 x 10^6**
Reliability	**Max**	**3.373 x 10^6**	Min	1.478 x 10^6	**1.895 x 10^6**
Local resources	**Max**	**3.560 x 10^6**	Min	0	**3.560 x 10^6**
Petroleum products	**Min**	**0**	Max	3.560 x 10^6	**-3.560 x 10^6**
Employment	**Max**	**2209.61**	Min	0.65	**2208.96**
Social acceptance	**Max**	**2.652 x 10^6**	Min	0.301 x 10^6	**2.351 x 10^6**
Carbon emission	**Min**	**0.422 x 10^6**	Max	2.887 x 10^6	**-2.465 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.090 x 10^6	**-0.090 x 10^6**
Nitrogen emission	**Min**	**116.61**	Max	0.025 x 10^6	**-0.025 x 10^6**

Table 5.9e Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura 1st-Morva* Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**3.524 x 10^6**	Max	81.950 x 10^6	**-78.426 x 10^6**
Efficiency	**Max**	**1.659 x 10^6**	Min	0.749 x 10^6	**0.910 x 10^6**
Reliability	**Max**	**5.187 x 10^6**	Min	2.191 x 10^6	**2.996 x 10^6**
Local resources	**Max**	**5.463 x 10^6**	Min	0	**5.463 x 10^6**
Petroleum products	**Min**	**0**	Max	5.463 x 10^6	**-5.463 x 10^6**
Employment	**Max**	**3502.28**	Min	0.99	**3501.29**
Social acceptance	**Max**	**4.070 x 10^6**	Min	0.458 x 10^6	**3.612 x 10^6**
Carbon emission	**Min**	**0.618 x 10^6**	Max	4.528 x 10^6	**-3.910 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.135 x 10^6	**-0.135 x 10^6**
Nitrogen emission	**Min**	**162.24**	Max	0.039 x 10^6	**-0.039 x 10^6**

Table 5.9f Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura 2nd-Morva* Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**3.532 x 10^6**	Max	82.416 x 10^6	**-78.884 x 10^6**
Efficiency	**Max**	**1.669 x 10^6**	Min	0.756 x 10^6	**0.913 x 10^6**
Reliability	**Max**	**5.217 x 10^6**	Min	2.227 x 10^6	**2.990 x 10^6**
Local resources	**Max**	**5.494 x 10^6**	Min	0	**5.494 x 10^6**
Petroleum products	**Min**	**0**	Max	5.494 x 10^6	**-5.494 x 10^6**
Employment	**Max**	**3495.14**	Min	1.00	**3494.14**
Social acceptance	**Max**	**4.093 x 10^6**	Min	0.462 x 10^6	**3.631 x 10^6**
Carbon emission	**Min**	**0.631 x 10^6**	Max	4.497 x 10^6	**-3.866 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.135 x 10^6	**-0.135 x 10^6**
Nitrogen emission	**Min**	**181.35**	Max	0.039 x 10^6	**-0.039 x 10^6**

Table 5.9g Goal Value, Worst Value and Weighting Factors for the Objectives in *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* Village-mix

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**4.073 x 10^6^**	Max	94.596 x 10^6	**-90.523 x 10^6**
Efficiency	**Max**	**1.912 x 10^6**	Min	0.865 x 10^6	**1.047 x 10^6**
Reliability	**Max**	**5.986 x 10^6**	Min	2.537 x 10^6	**3.449 x 10^6**
Local resources	**Max**	**6.306 x 10^6**	Min	0	**6.306 x 10^6**
Petroleum products	**Min**	**0**	Max	6.306 x 10^6	**-6.306 x 10^6**
Employment	**Max**	**3996.02**	Min	1.15	**3994.87**
Social acceptance	**Max**	**4.698 x 10^6**	Min	0.529 x 10^6	**4.169 x 10^6**
Carbon emission	**Min**	**0.716 x 10^6**	Max	5.219 x 10^6	**-4.503 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.157 x 10^6	**-0.157 x 10^6**
Nitrogen emission	**Min**	**186.81**	Max	0.045 x 10^6	**-0.045 x 10^6**

Optimal Scenario for Implementation: In this scenario, energy resource allocation is carried out with respect to objectives of regional development by assigning higher priority to cost and employment generation objective functions as compared to other objective functions. The results of energy resource allocation for *Panthadiya-Bisanpura 1st*, *Panthadiya-Bisanpura 2nd*, *Panthadiya-Morva, Panthadiya-Bisanpura 1st-Bisanpura 2nd*, *Panthadiya-Bisanpura 1st –Morva, Panthadiya-Bisanpura 2nd-Morva* and *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* village-mix are shown in Tables 5.10a to 5.10g.

Table 5.10a Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 1st* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 1st Village-mix	1. Biomass (13.99%) 2. LPG (24.87%) 3. Biogas (41.14%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10b Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 2nd* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 2nd Village-mix	1. Biomass (13.24%) 2. LPG (26.42%) 3. Biogas (40.34%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10c Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Morva* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Morva Village-mix	1. Biomass (18.39%) 2. LPG (24.50%) 3. Biogas (37.11%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10d Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 1st-Bisanpura 2nd* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 1st-Bisanpura 2nd Village-mix	1. Biomass (17.28%) 2. LPG (21.40%) 3. Biogas (41.32%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10e Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 1st-Morva* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 1st-Morva Village-mix	1. Biomass (16.63%) 2. LPG (25.19%) 3. Biogas (38.18%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10f Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 2nd-Morva* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 2nd-Morva Village-mix	1. Biomass (16.04%) 2. LPG (26.15%) 3. Biogas (37.81%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

Table 5.10g Energy Resource Allocation Pattern in Optimal Scenario for Implementation in *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* Village-mix

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Optimal Scenario for Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva Village-mix	1. Biomass (15.05%) 2. LPG (26.30%) 3. Biogas (38.65%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization for the inter village-mix show the similar results. The scenario analysis shows that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (21.40% to 26.42%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. The contribution of LPG for cooking end-use is observed to be proportional to the use of biogas. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs.

The cost associated with optimal scenario for Panthdiya-Bisanpura1st village-mix is Rs. 7.75 millions and the associated emissions are 1963.41, 3.22, 43.93 Tons/year for CO_X , NO_X and SO_X, respectively. The cost associated with optimal scenario for *Panthadiya-Bisanpura 2nd* village-mix is Rs. 7.37 millions and the associated emissions are 1883.95, 3.14, 43.50 Tons/year for CO_X , NO_X and SO_X, respectively. The cost associated with optimal scenario for *Panthadiya-Morva* village-mix is Rs. 12.64 millions and the associated emissions are 3725.67, 6.41, 71.53 Tons/year for CO_X , NO_X and SO_X, respectively. The cost associated with optimal scenario for *Panthadiya-Bisanpura 1st-Bisanpura 2nd* village-mix is Rs. 9.62 millions and the associated emissions are 2737.08, 4.70, 57.72 Tons/year for CO_x , NO_x and SO_x, respectively. The cost associated with optimal scenario for *Panthadiya-Bisanpura 1st-Morva* village-mix is Rs. 14.81 millions and the associated emissions are 4195.34, 7.14, 85.75 Tons/year for CO_x , NO_x and SO_x, respectively. The cost associated with optimal scenario for *Panthadiya-Bisanpura 2nd-Morva* village-mix is Rs. 14.88 millions and the associated emissions are 4140.06, 7.02, 85.34 Tons/year for CO_x , NO_x and SO_x, respectively. The cost associated with optimal scenario for *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* village-mix is Rs. 17.06 millions and the associated emissions are 4641.11, 7.81, 99.55 Tons/year for CO_x , NO_x and SO_x, respectively.

Tables 5.11 shows the unutilized energy resource in implementing optimal energy scenario for inter village-mix in the base year (2005-06).

Table 5.11 Estimated Unutilized Energy Resources in Optimal Scenario for Village-mix

Name of the Village	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Panthadiya-Bisanpura 1st	8.28×10^6	8.28×10^6	12.52×10^6	1.43×10^6
Panthadiya-Bisanpura 2nd	8.24×10^6	8.24×10^6	12.47×10^6	1.49×10^6
Panthadiya-Morva	13.47×10^6	13.47×10^6	23.36×10^6	2.46×10^6
Panthadiya-Bisanpura 1st-Bisanpura 2nd	10.91×10^6	10.91×10^6	15.73×10^6	---
Panthadiya-Bisanpura 1st-Morva	16.14×10^6	16.14×10^6	26.62×10^6	2.95×10^6
Panthadiya-Bisanpura 2nd-Morva	16.10×10^6	16.10×10^6	26.57×10^6	3.16×10^6
Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva	18.77×10^6	18.77×10^6	29.83×10^6	3.54×10^6

It can be observed that the dung cake (100%) is not allocated in any inter village-mix. Biomass energy resource 11.42%, 11.95%, 10.53%, 11.08%, 11.89% and 11.86% is not allocated in optimal scenario for *Panthadiya-Bisanpura 1st*, *Panthadiya-Bisanpura 2nd*, *Panthadiya-Morva*, *Panthadiya-Bisanpura 1st-Bisanpura 2nd*, *Panthadiya-Bisanpura 1st –Morva*, *Panthadiya-Bisanpura 2nd-Morva* and *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* village-mix respectively. The dung cake energy resource is not allocated for cooking end-use due to its higher associated emissions (0.633 kg/kWh, 0.0013 kg/kWh and 1.709 x 10^{-2} kg/kWh for Carbon, Sulphur and Nitrogen respectively). The biomass energy is unutilized is due to more potential of energy resource.

In micro-level energy planning, energy scenario when implemented is required to fulfill the objective of meeting energy requirement subject to certain constraints. These constraints correspond to resource availability, technology options, cost of utilization, environmental impact, socio-economic impact, employment generation, subject to present as well as future considerations. The success of implementation of energy scenario will depend on how accurate is the estimation of energy resource, energy demand and unutilized local energy resource. The quantum of unutilized local energy resource will decide sustainability of the plan, when implemented.

The region for fast track IRES development is defined with respect to available energy sources and energy demand. The results of inter village-mix for present energy requirements for different end-uses show that the dung cake energy resource is not to be preferred in optimal energy resource allocation due to associated higher emissions. Moreover, the unutilized energy resource potential of biomass energy can be observed from Table 5.11 for the inter village-mix with *Panthadiya* village. The results of inter village-mix show that *Panthadiya-Bisanpura 2nd* village-mix has maximum unutilized local energy potential. Therefore, *Panthadiya-Bisanpura 2nd* village-mix is identified as a region for energy planning.

5.3 ENERGY PLANNING FOR THE REGION

As discussed in previous article *Panthadiya-Bisanpura 2nd* village-mix is identified as a region for IRES design for future energy requirements. In IRES design for the region, energy plans are developed for short and medium term objectives. In short term energy planning, objectives to be achieved are minimum cost of energy utilization, maximum employment generation and maximum use of local resource. In medium term planning, objectives to be achieved are minimum cost of energy utilization, maximum employment generation, maximum use of local resource and minimum environment emissions. The short and medium term plans are generated for the projected end-use energy requirements and estimated energy resource availability in the region.

5.3.1 Short term energy planning for the region

Short term energy plans are developed for the region by considering the expected end-use energy requirements in the year 2010-11. Table 5.12 shows the projected end-use energy requirement for the region in year 2010-11. The average per capita energy consumption in *Panthadiya* and *Bisanpura 2nd* is used to project future end-use energy requirements. For pumping end-use, during the survey it is observed that on an average 2 tube wells are added every year in the agricultural application. This lower increase in pumping energy requirements is due to higher initial cost for constructing a tube well.

Table 5.12 Estimated End-use Energy Requirement for the region in 2010-11

End-use	*Annual energy requirement MWh/yr*
Cooking	1.421×10^3
Lighting	0.101×10^3
Pumping	1.253×10^3
Heating	0.191
Cooling	0.220×10^3
Appliances	0.054×10^3

The cost of energy utilization is computed by considering inflation rate of 6% and escalation rate of 6% for petroleum products. The projected unit cost of energy (Rs/kWh) is shown in Table 5.13.

Table 5.13 Projected Unit Cost of Energy Resource associated with Different Resource-End-use Combinations (Rs/kWh) in the year 2010

Energy resources	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Dung cake	0.42	---	---	0.42	---	---
Biomass	0.96	---	---	0.96	---	---
LPG	3.06	---	---	---	---	---
Kerosene	1.47	1.47	---	---	---	---
Biogas	0.36	0.36	---	0.36	---	---
Solar Thermal	0.50	---	---	0.50	---	---
Biogas electricity	1.67	1.67	1.67	1.67	1.67	1.67
Biomass electricity	3.35	3.35	3.35	3.35	3.35	3.35
PV electricity	20.07	20.07	---	20.07	20.07	20.07
Diesel electricity	26.85	26.85	26.85	26.85	26.85	26.85
Grid electricity	4.01	4.01	1.00	4.01	4.01	4.01

5.3.1.1 Scenario 1- Base-case energy scenario

In Scenario 1, it is assumed that the biomass energy resource availability in 2010-11 will remain same as that of the base year (2005-06) and for biogas energy resource, the number of cattle to population ratio (0.51) is assumed to remain constant. Table 5.14 shows the projected energy resource availability in the region.

Table 5.14 Projected Energy Resource Availability in the Region for 2010-11

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2620	648	12.47 x 10^6	1336	9.14 x 10^6	4.17 x 10^6

In scenario 1, it assumed that system efficiency, reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.15.

Table 5.15 Goal Value, Worst Value and Weighting Factors for the Objectives in the Region

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**4.839 x 10^6**	Max	81.871 x 10^6	**-77.032 x 10^6**
Efficiency	**Max**	**0.918 x 10^6**	Min	0.427 x 10^6	**0.491 x 10^6**
Reliability	**Max**	**2.887 x 10^6**	Min	1.307 x 10^6	**1.580 x 10^6**
Local resources	**Max**	**3.049 x 10^6**	Min	0	**3.049 x 10^6**
Petroleum products	**Min**	**0**	Max	3.049x 10^6	**-3.049 x 10^6**
Employment	**Max**	**1804.23**	Min	0.55	**1803.68**
Social acceptance	**Max**	**2.271 x 10^6**	Min	0.259 x 10^6	**2.012 x 10^6**
Carbon emission	**Min**	**0.379 x 10^6**	Max	2.365 x 10^6	**-1.986 x 10^6**

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Sulphur emission	**Min**	**0**	Max	0.076 x 10^6	**-0.076 x 10^6**
Nitrogen emission	**Min**	**126.75**	Max	0.021 x 10^6	**-0.021 x 10^6**

In scenario 1, energy resource allocation is carried out with respect short term objectives of energy planning. In scenario 1, cost, employment generation and use of local resources objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.16.

Table 5.16 Energy Resource Allocation in Scenario 1 for 2010-11

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 1	1. LPG (39.18%) 2. Biogas (40.82%) 3. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that LPG, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (39.18%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential and is preferred over dung cake due to the lower associated emissions and higher system efficiency. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 1 is Rs. 11.60 millions and the associated emissions are 1331.85, 1.84, 48.54 Tons/year for CO_x, NO_x and SO_x, respectively.

5.3.1.2 Scenario 2 – Biogas energy scenario

In scenario 2, it is assumed that the population to cattle ratio increases from present i.e. 0.51 by 20% in the future to 0.612 and biomass energy resource remains unchanged due to more dependence on firewood collection from the region as compared to agriculture residue. Table 5.17 shows the projected energy resource availability in the region.

Table 5.17 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2620	648	12.47×10^6	1603	10.97×10^6	5.01×10^6

In scenario 2, it assumed that system efficiency, reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.18.

Table 5.18 Goal Value, Worst Value and Weighting Factors for the Objectives in the Region

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	$\mathbf{4.416 \times 10^6}$	Max	81.871×10^6	$\mathbf{-77.455 \times 10^6}$
Efficiency	**Max**	$\mathbf{0.928 \times 10^6}$	Min	0.427×10^6	$\mathbf{0.501 \times 10^6}$
Reliability	**Max**	$\mathbf{2.888 \times 10^6}$	Min	1.307×10^6	$\mathbf{1.581 \times 10^6}$
Local resources	**Max**	$\mathbf{3.049 \times 10^6}$	Min	0	$\mathbf{3.049 \times 10^6}$
Petroleum products	**Min**	**0**	Max	3.049×10^6	$\mathbf{-3.049 \times 10^6}$
Employment	**Max**	**1986.93**	Min	0.55	**1986.38**
Social acceptance	**Max**	$\mathbf{2.271 \times 10^6}$	Min	0.259×10^6	$\mathbf{2.012 \times 10^6}$

5.3.1.2 Scenario 2 – Biogas energy scenario

In scenario 2, it is assumed that the population to cattle ratio increases from present i.e. 0.51 by 20% in the future to 0.612 and biomass energy resource remains unchanged due to more dependence on firewood collection from the region as compared to agriculture residue. Table 5.17 shows the projected energy resource availability in the region.

Table 5.17 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2620	648	12.47 x 10^6	1603	10.97 x 10^6	5.01 x 10^6

In scenario 2, it is assumed that system efficiency, reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.18.

Table 5.18 Goal Value, Worst Value and Weighting Factors for the Objectives in the Region

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**4.416 x 10^6**	Max	81.871 x 10^6	**-77.455 x 10^6**
Efficiency	**Max**	**0.928 x 10^6**	Min	0.427 x 10^6	**0.501 x 10^6**
Reliability	**Max**	**2.888 x 10^6**	Min	1.307 x 10^6	**1.581 x 10^6**
Local resources	**Max**	**3.049 x 10^6**	Min	0	**3.049 x 10^6**
Petroleum products	**Min**	**0**	Max	3.049 x 10^6	**-3.049 x 10^6**
Employment	**Max**	**1986.93**	Min	0.55	**1986.38**
Social acceptance	**Max**	**2.271 x 10^6**	Min	0.259 x 10^6	**2.012 x 10^6**

Objective function		*Goal (b_j)*		*Worst value (L_j)*	*Weighting factor (w_j)*
Carbon emission	**Min**	**0.374 x 10^6**	Max	2.391 x 10^6	**-2.017 x 10^6**
Sulphur emission	**Min**	**0**	Max	0.087 x 10^6	**-0.087 x 10^6**
Nitrogen emission	**Min**	**54.37**	Max	0.023 x 10^6	**-0.023 x 10^6**

In scenario 2, energy resource allocation is carried out with respect short term objectives of energy planning. In scenario 2, cost, employment generation and use of local resources objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.19.

Table 5.19 Energy Resource Allocation in Scenario 2 for 2010-11

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 2	1. LPG (31.04%) 2. Biogas (56.18%) 3. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of analysis of scenario show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (31.04%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 2 is Rs. 10.97 millions and the associated emissions are 1333.97, 1.84, 58.20 Tons/year for CO_X, NO_X and SO_X, respectively.

5.3.1.3 Scenario 3 – Biomass energy scenario

In Scenario 3, it is assumed that the biomass energy potential increases by 20% in the future and for biogas energy resource, the number of cattle to population ratio (0.51) is assumed to remain same as that estimated in the base year (2005-06). The estimated future energy availability is shown in Table 5.20. In scenario 3, it assumed that reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.21.

Table 5.20 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2620	648	14.72×10^6	1336	9.14×10^6	4.17×10^6

Table 5.21 Goal Value, Worst Value and Weighting Factors for the Objectives in Scenario 3

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**4.788×10^6**	Max	81.871×10^6	**-77.083×10^6**
Efficiency	**Max**	**0.918×10^6**	Min	0.427×10^6	**0.491×10^6**
Reliability	**Max**	**2.888×10^6**	Min	1.307×10^6	**1.581×10^6**
Local resources	**Max**	**3.049×10^6**	Min	0	**3.049×10^6**
Petroleum products	**Min**	**0**	Max	3.049×10^6	**-3.049×10^6**
Employment	**Max**	**1958.77**	Min	0.55	**1958.22**
Social acceptance	**Max**	**2.271×10^6**	Min	0.259×10^6	**2.012×10^6**
Carbon emission	**Min**	**0.379×10^6**	Max	2.409×10^6	**-2.030×10^6**
Sulphur emission	**Min**	**0**	Max	0.076×10^6	**-0.076×10^6**
Nitrogen emission	**Min**	**127.37**	Max	0.021×10^6	**-0.021×10^6**

In scenario 3, energy resource allocation is carried out with respect short term objectives of energy planning. In scenario 3, cost, employment generation and use of local resources objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.22.

Table 5.22 Energy Resource Allocation in Scenario 3 for 2010-11

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 3	1. LPG (39.25%) 2. Biogas (40.75%) 3. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The scenario indicates that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (39.25%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 3 is Rs. 11.60 millions and the associated emissions are 1331.82, 1.84, 48.46 Tons/year for CO_X , NO_X and SO_X, respectively.

5.3.1.4 Analysis of Scenario for Short-term Planning

The developed scenarios are analyzed with respect to unutilized energy source and associated cost and are shown in Table 5.23. It can be observed that in Scenario 1 and Scenario 2, 34.32% of biomass energy is not allocated in energy resource allocation. In all the scenarios dung cake energy is not allocated for cooking or heating end-use. Therefore, the dung cake energy source can be transferred to biogas energy source or can be utilized in agricultural applications. In scenario 3, 44.36% of biomass energy resource is not utilized. Therefore, Scenario 3 should only be preferred for implementation when required biomass potential in a region can be increased by means of afforestation.

Table 5.23 Estimated Unutilized Energy Resources in Scenarios for the Region

Name of the Scenario	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Biogas availability, MJ/year*	*Unutilized Biogas availability, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Base case scenario	9.14×10^6	9.14×10^6	4.495×10^6	0	12.47×10^6	4.28×10^6
Biogas energy scenario	10.97×10^6	10.97×10^6	5.01×10^6	0	12.47×10^6	4.28×10^6
Biomass energy scenario	9.14×10^6	9.14×10^6	4.17×10^6	0	14.72×10^6	6.53×10^6

In all the scenarios, biomass electricity is allocated for lighting, pumping, cooling and appliance end-uses. The energy allocation for cooking end-use in scenario 1 and scenario 2 show that, the share of LPG and Biogas changes when the number of cattle to population changes from 0.51 to 0.612. Therefore, Scenario 2 should be preferred for implementation wherein LPG is to be allocated for 31.04%, Biogas is to be allocated for 48.96% and solar thermal for 20% of total cooking energy requirements.

5.3.2 Medium-term Energy Planning for the Region

Medium term energy plans are developed for region considering expected energy demand for the year 2015. Table 5.24 shows the expected energy demand for the region in year 2015-16. The average per capita energy consumption in *Panthadiya* and *Bisanpura 2nd* villages is used to project future energy requirements. For pumping end-use it is assumed that every year 2 tube wells will be added in the agricultural application. The cost associated with constructing a tube well depends on the water table available.

The lower rate of increase is assumed due to the lower water table observed in the region, which is below 300 feet.

Table 5.24 Estimated End-use Energy Requirement for the Region in 2015-16

End-use	*Annual energy requirement MWh/yr*
Cooking	1.571 x 10^3
Lighting	0.111 x 10^3
Pumping	1.389 x 10^3
Heating	0.211
Cooling	0.242 x 10^3
Appliances	0.060 x 10^3

The cost of energy utilization is computed by considering inflation rate of 6% and escalation rate of 6% for petroleum products. The projected unit cost of energy (Rs/kWh) is shown in Table 5.25.

Table 5.25 Projected Unit Cost of Energy Resource associated with Different Resource-End-use Combinations (Rs/kWh) in the year 2015-16

Energy resources	*Cooking*	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Dung cake	0.56	---	---	0.56	---	---
Biomass	1.29	---	---	1.29	---	---
LPG	5.49	---	---	---	---	---
Kerosene	2.63	2.63	---	---	---	---
Biogas	0.48	0.48	---	0.48	---	---
Solar Thermal	0.66	---	---	0.66	---	---
Biogas electricity	2.24	2.24	2.24	2.24	2.24	2.24
Biomass electricity	4.48	4.48	4.48	4.48	4.48	4.48
PV electricity	26.87	26.87	---	26.87	26.87	26.87
Diesel electricity	48.15	48.15	48.15	48.15	48.15	48.15
Grid electricity	5.37	5.37	5.37	5.37	5.37	5.37

5.3.2.1 Scenario 1 – Base-case energy scenario

In Scenario 1, it is assumed that the biomass energy resource availability in 2015-16 will remain same as that of the base year (2005-06) and for biogas energy resource, the number of cattle to population ratio (0.51) is assumed to remain constant. Table 5.26 shows the projected energy resource availability in the region.

Table 5.26 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2895	648	12.47×10^6	1476	10.10×10^6	4.61×10^6

In scenario 1, it assumed that system efficiency, reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.27.

Table 5.27 Goal Value, Worst Value and Weighting Factors for the Objectives

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	Min	**7.525×10^6**	Max	162.420×10^6	**-154.895×10^6**
Efficiency	Max	**1.016×10^6**	Min	0.472×10^6	**0.544×10^6**
Reliability	Max	**3.194×10^6**	Min	1.449×10^6	**1.745×10^6**
Local resources	Max	**3.373×10^6**	Min	0	**3.373×10^6**
Petroleum products	Min	**0**	Max	3.373×10^6	**-3.373×10^6**
Employment	Max	**1904.25**	Min	0.61	**1903.64**
Social acceptance	Max	**2.513×10^6**	Min	0.287×10^6	**2.226×10^6**
Carbon emission	Min	**0.420×10^6**	Max	2.583×10^6	**-2.163×10^6**
Sulphur emission	Min	**0**	Max	0.084×10^6	**-0.084×10^6**

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Nitrogen emission	**Min**	**142.04**	Max	0.024×10^6	**-0.024×10^6**

In scenario 1, energy resource allocation is carried out with respect medium term objectives of energy planning. In scenario 1, cost, employment generation, use of local resources and environment emissions objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.28.

Table 5.28 Energy Resource Allocation in Scenario 1 for 2015-16

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 1	1 Biomass (10.25%) 2. LPG (28.99%) 3. Biogas (40.76%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (28.99%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with Scenario 1 is Rs. 18.33 millions and the associated emissions are 2118.062, 6.00, 53.57 Tons/year for CO_X, NO_X and SO_X, respectively.

5.3.2.2 Scenario 2 – Biogas energy scenario

In scenario 2, it is assumed that the population to cattle ratio increases from present i.e. 0.51 by 20% in the future to 0.612 and biomass energy resource remains unchanged due to more dependence on firewood collection from the region as compared to agriculture residue. Table 5.29 shows the projected energy resource availability in the region.

Table 5.29 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2895	648	12.47×10^6	1772	12.13×10^6	5.54×10^6

In scenario 2, it assumed that system efficiency, reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.30.

Table 5.30 Goal Value, Worst Value and Weighting Factors for the Objectives

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	6.805×10^6	Max	162.420×10^6	-155.615×10^6
Efficiency	**Max**	1.026×10^6	Min	0.472×10^6	0.554×10^6
Reliability	**Max**	3.194×10^6	Min	1.449×10^6	1.745×10^6
Local resources	**Max**	3.373×10^6	Min	0	3.373×10^6
Petroleum products	**Min**	**0**	Max	3.373×10^6	-3.373×10^6
Employment	**Max**	**2105.90**	Min	0.61	**2105.29**
Social acceptance	**Max**	2.513×10^6	Min	0.287×10^6	2.226×10^6
Carbon emission	**Min**	0.414×10^6	Max	2.612×10^6	-2.198×10^6

Objective function		Goal (b_j)		Worst value (L_j)	Weighting factor (w_j)
Sulphur emission	**Min**	**0**	Max	0.096 x 10^6	**-0.096 x 10^6**
Nitrogen emission	**Min**	**61.23**	Max	0.025 x 10^6	**-0.025 x 10^6**

In scenario 2, energy resource allocation is carried out with respect to medium term objectives of energy planning. In scenario 2, cost, employment generation, use of local resources and environment emissions objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.31.

Table 5.31 Energy Resource Allocation in Scenario 2 for 2015-16

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 2	1. Biomass (10.25%) 2. LPG (20.75%) 3. Biogas (49.00%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (20.75%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 2 is Rs. 17.03 millions and the associated emissions are 2039.44, 6.00, 64.38 Tons/year for CO_x , NO_x and SO_x, respectively.

5.3.2.3 Scenario 3 – Biomass energy scenario

Objective function		*Goal (b_j)*		*Worst value (L_j)*	*Weighting factor (w_j)*
Sulphur emission	**Min**	**0**	Max	0.096 x 10^6	**-0.096 x 10^6**
Nitrogen emission	**Min**	**61.23**	Max	0.025 x 10^6	**-0.025 x 10^6**

In scenario 2, energy resource allocation is carried out with respect to medium term objectives of energy planning. In scenario 2, cost, employment generation, use of local resources and environment emissions objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.31.

Table 5.31 Energy Resource Allocation in Scenario 2 for 2015-16

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 2	1. Biomass (10.25%) 2. LPG (20.75%) 3. Biogas (49.00%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (20.75%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 2 is Rs. 17.03 millions and the associated emissions are 2039.44, 6.00, 64.38 Tons/year for CO_x , NO_x and SO_x, respectively.

5.3.2.3 Scenario 3 – Biomass energy scenario

In Scenario 3, it is assumed that the biomass energy potential increases by 20% in the future and for biogas energy resource, the number of cattle to population ratio (0.51) is assumed to remain same as that estimated in the base year (2005-06). The estimated future energy availability is shown in Table 5.32. In scenario 3, it assumed that reliability of the energy source and system, social acceptance factors and employment generation rate and environment emission rates will remain same as observed in the year base year (2005-06). The multi-objective optimization problem is solved for the projected end-use energy requirements and resource availability in the region. The goal value, worst value and weighting factor for different objective functions in the region are shown in Table 5.33.

Table 5.32 Estimated Future Energy Resource Availability in the Region

Population	*Irrigated Land (in hectors)*	*Biomass energy available, MJ/year*	*Number of Cattle*	*Dung cake availability, MJ/yr*	*Biogas availability, MJ/year*
2895	648	14.72×10^6	1772	12.13×10^6	5.54×10^6

Table 5.33 Goal Value, Worst Value and Weighting Factors for the Objectives

Objective function	*Goal (b_j)*		*Worst value (L_j)*		*Weighting factor (w_j)*
Cost	**Min**	**6.662×10^6**	Max	162.420×10^6	**-155.758×10^6**
Efficiency	**Max**	**1.026×10^6**	Min	0.472×10^6	**0.554×10^6**
Reliability	**Max**	**3.194×10^6**	Min	1.449×10^6	**1.745×10^6**
Local resources	**Max**	**3.373×10^6**	Min	0	**3.373×10^6**
Petroleum products	**Min**	**0**	Max	3.373×10^6	**-3.373×10^6**
Employment	**Max**	**2260.93**	Min	0.61	**2260.32**
Social acceptance	**Max**	**2.513×10^6**	Min	0.287×10^6	**2.226×10^6**
Carbon emission	**Min**	**0.410×10^6**	Max	2.656×10^6	**-2.246×10^6**
Sulphur emission	**Min**	**0**	Max	0.096×10^6	**-0.096×10^6**
Nitrogen emission	**Min**	**61.23**	Max	0.025×10^6	**-0.025×10^6**

In scenario 3, energy resource allocation is carried out with respect to medium term objectives of energy planning. In scenario 3, cost, employment generation, use of local resources and environment emissions objective functions are assigned a higher priority as compared to other objective functions. The results of energy resource allocation are shown in Table 5.34.

Table 5.34 Energy Resource Allocation in Scenario 3 for 2015-16

Objective Function	*End-uses*					
	Cooking	*Lighting*	*Pumping*	*Heating*	*Cooling*	*Appliances*
Scenario 3	1. Biomass (17.00%) 2. LPG (13.97%) 3. Biogas (49.03%) 4. Solar thermal (20%)	Biomass electricity (100%)	Biomass electricity (100%)	Solar thermal (100%)	Biomass electricity (100%)	Biomass electricity (100%)

The results of optimization show that biomass, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (13.97%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with scenario 3 is Rs. 16.67 millions and the associated emissions are 2464.61, 4.37, and 64.37 Tons/year for CO_x , NO_x and SO_x, respectively.

5.3.2.4 Analysis of Scenario for Medium-term Planning

The developed scenarios are analyzed with respect to unutilized energy source and associated cost and are shown in Table 5.35. It can be observed that in all the scenarios, 100% of dung cake energy is not allocated in energy resource allocation. In all the scenarios, biomass and biogas energy is allocated for different end-uses. Therefore, the dung cake energy source can be transferred to biogas energy source or can be utilized in agricultural applications. In all the scenarios, biomass electricity is allocated for lighting, pumping, cooling and appliance end-uses and solar thermal energy is allocated for heating end-use. The cost associated with Scenario 3 is less as compared to the other scenarios and this scenario is recommended for implementation if in short term planning biogas energy scenario is implemented. This is due to the reason that in this scenario 20% increase in firewood potential is assumed that can only be achieved when the energy efficient trees are planted in the region. The yield of such can only be realized after 2 to 3 years of plantation.

Table 5.35 Estimated Unutilized Energy Resources in Medium-term Scenarios for the Region

Name of the Village	*Estimated dung cake availability, MJ/year*	*Unutilized dung cake, MJ/year*	*Biogas availability, MJ/year*	*Unutilized Biogas availability, MJ/year*	*Estimated biomass energy availability, MJ/year*	*Unutilized biomass energy availability, MJ/year*
Base case scenario	10.10×10^6	10.10×10^6	4.61×10^6	0	12.47×10^6	0
Biogas energy scenario	12.13×10^6	12.13×10^6	5.54×10^6	0	12.47×10^6	0
Biomass energy scenario	12.13×10^6	12.13×10^6	5.54×10^6	0	14.72×10^6	0

The energy resource allocation in scenario 3 shows that biomass, biogas and solar thermal energy should be promoted for cooking, and solar thermal for heating end-use. LPG (13.97%) is to be allocated for cooking end-use. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses.

The next chapter presents the selection of system sizing for the implementation scenario followed by recommended mechanism for implementation of region dependent IRES projects.

Chapter 6: IRES Implementation

In this chapter, selection of system size for electricity generation using HOMER software is presented. In Chapter 5, it is shown that for micro-level energy planning, short term energy plans should be preferred over the medium term plans, due to rapid changes in energy requirements. It is also observed that the objectives of medium term plans are satisfied in the short term plans. In order to implement plan in a region, selection of systems for electricity generation is important. In the literature survey, it is observed that different methodologies are recommended for sizing renewable energy source such as PV alone, Wind alone, and hybrid PV-Wind generation system. The results of scenario analysis show that use of biomass electricity is to be promoted for electrical end-uses.

The large number of technology options and the variation in cost of technology and availability of energy resources makes the selection of system more difficult. Therefore, in the present study HOMER (Hybrid Optimization Model for Electric Renewable) software is used to select system for meeting estimated energy requirement in the year 2010-11. In this chapter, the system sizing method using HOMER software is discussed and different scenarios are developed to estimate the required size of system to be implemented. Using HOMER, different scenarios are developed by changing the deferred load, which in this case is end-use energy requirement for pumping applications in agriculture. The discussion on the barriers in implementing IRES plan at the regional level is also presented followed by recommended mechanism to overcome these barriers.

6.1 INTRODUCTION

System sizing at the energy planner's level involves selection of system which will satisfy the estimated energy requirements over certain time period. While selecting the system, there is need to consider the pattern of energy usage. If the energy use pattern is not optimal then it will result in higher capacity of system. Optimal energy use pattern will result in optimal system capacity, which will result in lower cost of energy. In the present study, HOMER software is used to estimate the size of the system required to meet the electrical end-use energy requirements of household and agricultural applications.

6.2 SYSTEM SIZING USING HOMER

The HOMER software is developed by National Renewable Energy Laboratory (NREL), USA. In the present study, 2.2 beta version is used. The software is an optimization model, which can be used to evaluate designs of standalone and/or grid-connected power systems. In the software, different power generation technologies such as PV, Wind, Biomass gasifier, Dual fuel Diesel generator and hydro power, based on their availability in the region can be incorporated for meeting the estimated energy requirements. The optimization and sensitivity analysis available makes the evaluation of possible system combinations.

In order to select the system, simulations of operation for 8,760 hours in a year is required to balance energy supply and demand. For each hour, energy generation and energy demand is required to be compared and optimal flow of energy is required to be identified from each component of the system to meet the energy demand. The software helps the energy planner to perform energy balance calculations for each system configuration. It also helps in determining, whether a configuration is feasible for estimated energy demand, and estimates the cost of installation and operation of the system configuration over the lifetime of the project. The energy system cost usually includes costs associated with capital, replacement, operation and maintenance, fuel, and interest rate.

After simulating all of the possible system configurations, possible energy system combinations, which will meet the estimated energy demand, are required to be evaluated on the basis of associated life cycle cost for implementation. The sensitivity analysis of cost associated with fuel is required to evaluate to estimate the effect on the cost of electricity generation.

6.2.1 Salient Features of HOMER

The Salient features of HOMER are

- The software facilitate energy planner to simulate the energy generation system. It also provides optimization of the system design for cost-effective operation. The sensitivity analysis for factors such as resource availability and system costs provides better insight of cost of electricity generation.
- The software is an hourly simulation model. In the analysis, it is assumed that the energy flows and costs remain constant over the given hour. The simulations are performed on hourly resource data from monthly averages. The hourly resource data is used as basis to calculate energy generation per hour.
- The software is based on an econometric model. The energy planner can use the tool to compare different combinations of component sizes and quantities. It

assists in comparing the effect of variations in resource availability and system costs on the cost of electricity generation of different system designs.

6.2.2 System Sizing through HOMER

There are five principal parts of the software, such as input frame, search space frame, optimization and sensitivity variable frame, the control frame and the output pages and are shown in Figure 6.1.

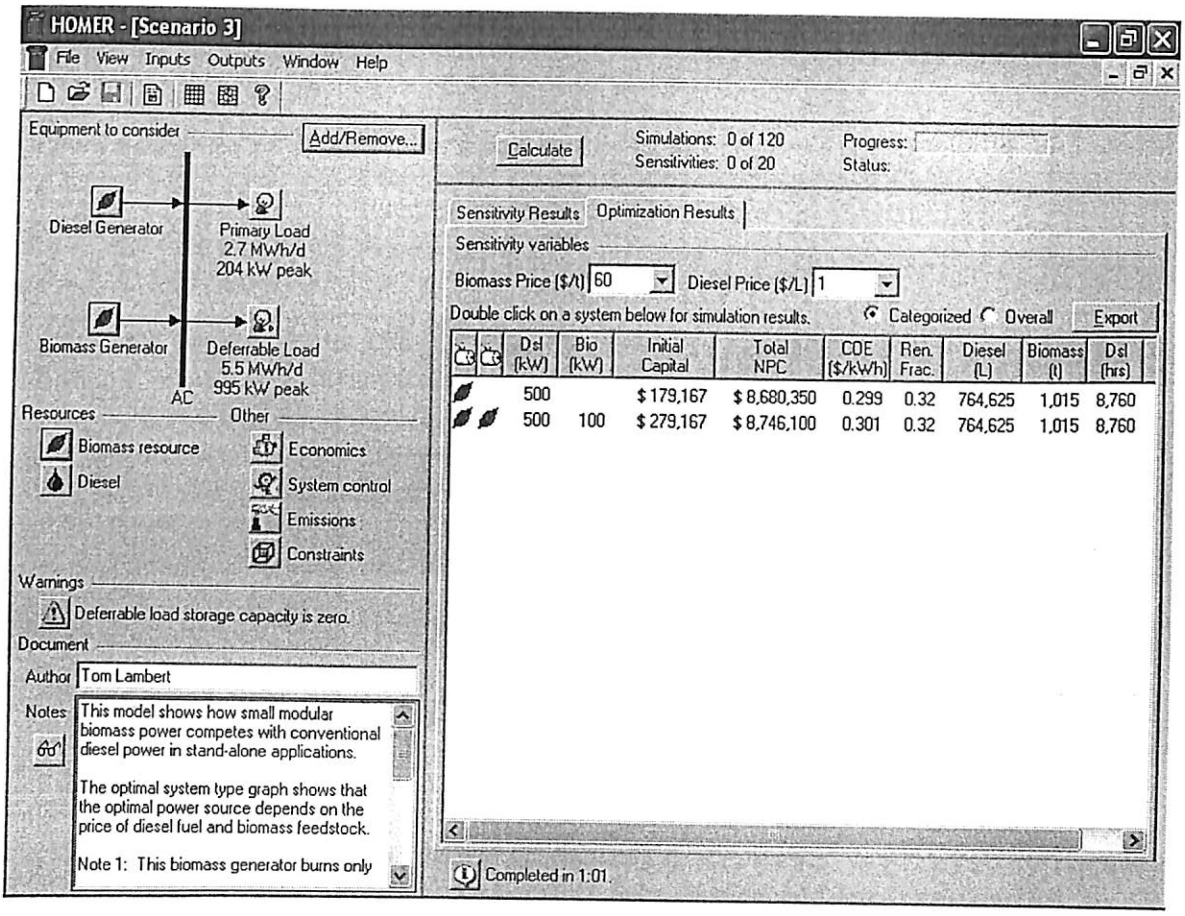

Figure 6.1 Main Screen of HOMER

1. The input frame includes load data, resource inputs, component inputs and optimization inputs. The load can be categorized as primary and deferred load. Primary load is defined as the electrical load that must be met immediately, which is essentially a household electricity requirement in present study. Deferred load is defined as the electrical load that must be met within some time period, but the

exact timing is not important, which is an agricultural pumping energy requirement in present study, which can be met at any time in a day.

2. The search space is defined as the set of systems and their sizes for which optimization is required to be performed. The search space can be provided by different system sizes and quantities of the different system components.
3. The optimization and sensitivity variable frame sensitivity analysis can be performed by providing multiple values for a particular input variable. The software repeats the optimization process for each value and shows the results. The software simulates every system of the search space and ranks all the feasible systems according to increasing life cycle cost associated with the combinations.
4. The control frame can be used to select the dispatch strategy that governs the operation of the generators and the battery bank. The software provides modeling of two dispatch strategies, cycle charging and load following. In cycle charging strategy, it is assumed that whenever a generator needs to operate to serve the primary load, it operates at full output power. The surplus electrical production if available is diverted towards satisfying the deferrable load or charging the battery bank. In load following strategy, it is assumed that whenever a generator operates, it produces only enough power to meet the primary load. In this strategy, charging the battery bank or meeting the deferrable load requirement renewable energy power sources are considered.

6.2.3 Data Analysis Using HOMER

As discussed in the previous article hourly energy requirements, need to be entered in the software. In the present case, it is assumed that the household energy requirements are the first priority and referred as primary load and agricultural pumping end-use is the next priority, which is referred as a deferred load. Figure 6.2 shows the typical load cure of household energy requirements against the hour of the day.

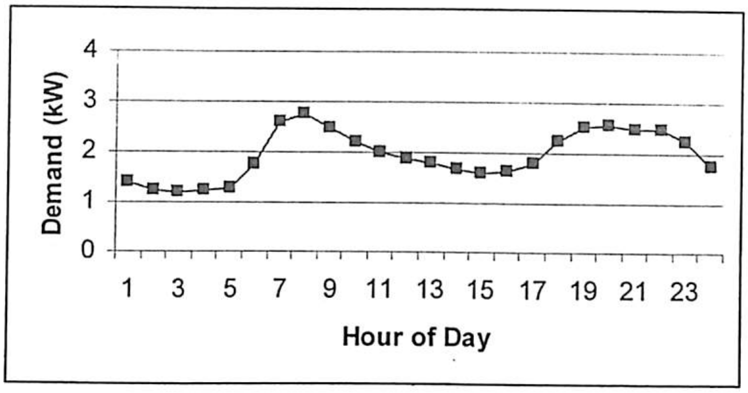

Figure 6.2 Hourly Average Demand of a Typical Residence (Source: Kellogg *et al.* 1998)

In the absence of actual load pattern,
It is assumed that the same pattern of energy usage is applicable to the region under investigation. The hourly energy requirements for household end-uses are calculated for the year 2010-11 and shown in Figure 6.3. It can be seen that the maximum load is observed in morning hours (7 am to 9 am) and in evening hours (6 pm to 9 pm) of the day. Based on these hourly energy demand values, the software calculates the annual average load of the region and is observed to be 2730 kWh/day and with an estimated peak load of 204 kW.

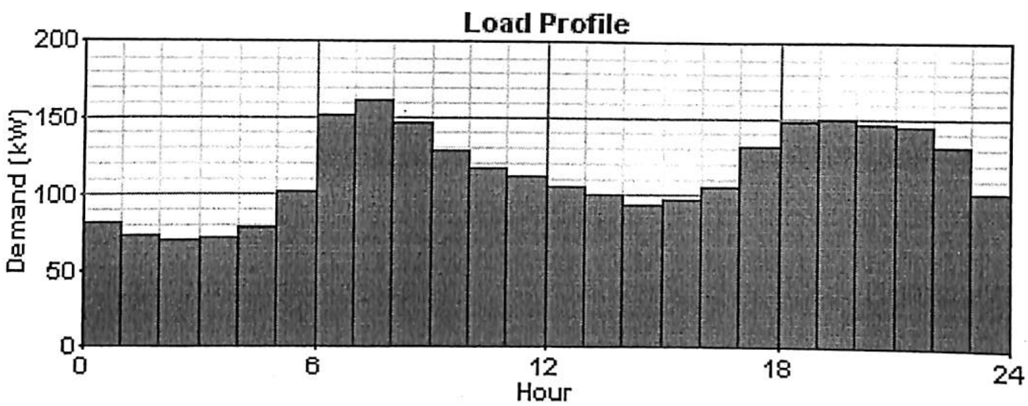

Figure 6.3 Hourly Average Demand for Household End-uses in the Region for 2010-11

The agricultural load is assumed be a deferred load, due to priority in meeting the energy requirements and is assumed that it will remain same throughout the year. Figure 6.4 shows the agricultural pumping end-use pattern for the region in 2010-11.

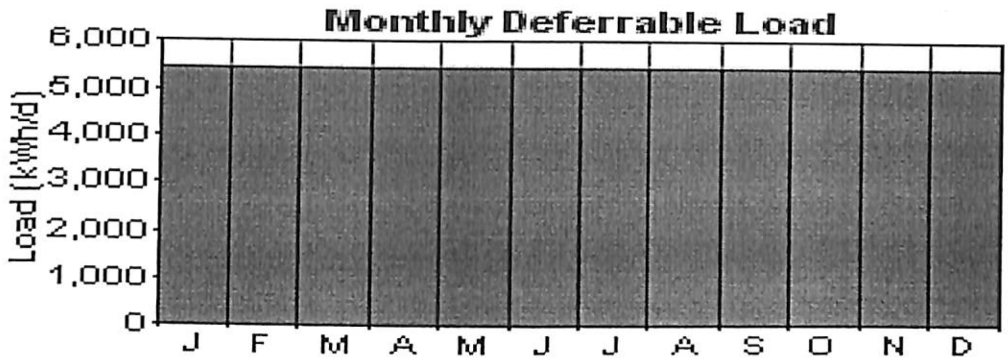

Figure 6.4 Agricultural Pumping End-use Pattern for the Region in 2010-11

Based on these monthly energy demand values for pumping end-use, the annual average load of the region is calculated and is observed to be 5.5 MWh/day. The peak load is calculated on the basis of operation of 89 tube wells of 12.5 hp capacity in the year 2010-11 and is observed to be 995 kW.

The energy system components are selected on the basis of energy resource allocation pattern, corresponding to scenario for the year 2010-11. Optimal energy resource allocations for the year 2010-11, show the allocation of biomass electricity for different end-uses such as lighting, pumping, cooling and appliances. Therefore, while selecting system components, biomass gasifier and Dual fuel diesel generator with producer gas as a supplementing fuel is used for the analysis.

In the Dual fuel diesel engine operation, it is assumed that the substitution ratio for diesel to producer gas be 3.5 (Ankur, 2005). The substitution ratio is defined as the ratio with which the producer gas replaces the diesel fuel in a dual fuel operation of the generator. The minimum diesel fuel fraction required for engine operation is assumed to be 20 (Tinaut *et al.*, 2006) i. e. the generator will operate on 80:20 ratio of producer gas and diesel fuel.

It is known that dual fuel diesel generator have higher brake thermal efficiency (around 28%), therefore it is selected in the analysis. It is known that the brake thermal efficiency of biomass gasifire when operated on full load is around 6%. Following data is employed in the software to size the system.

Table 6.1 Data Employed in the Software

Data input	*Unit*
Biomass resource potential	2.7 Tons/day
Gasification ratio	0.8
Calorific value of produce gas	20 MJ/kg
*Cost of Biomass gasifier**	1000 $/kW
*Cost of dual-fuel diesel engine generator**	1000 $/kW
*Operation and maintenance cost of Biomass gasifier**	1.5% $/kWh
*Operation and maintenance cost of dual-fuel diesel engine generator**	1 % $/kWh
Project life time	10 years
Annual interest rate	6 %

*(NREL, 2005)

(1 U.S. dollar = 45 Indian rupee)

Three different scenarios are generated by changing the deferred load. In scenario 1, it assumed that the agriculture pumping energy requirement is spread over the year. In Scenario 2 and Scenario 3, it is assumed that the agricultural pumping end-use energy requirements need to be met in seven and nine months of the year respectively.

6.2.3.1 Scenario 1

In this scenario, capacity of dual-fuel generator is varied from 100 kW to 1000 kW and the capacity of biomass generator is varied from 100 kW to 1500 kW to evaluate possible combinations for meeting energy requirements. The results of optimization are shown in Table 6.2. The cost of electricity is calculated on the basis of present cost of biomass as 60 $/tons and 0.7 $/lit diesel fuel cost. The net present cost is calculated on the basis of the present value of the cost of installing and operating the system over the lifetime of the project. From the Table 6.2, it can be observed that the 400 kW generator with dual-fire operation should be installed in the region. This system is to be preferred only when the agricultural pumping end-use requirement is distributed over the year.

Table 6.2 Capacity of Dual-Fire Diesel Generator, Biomass Generator, Initial Capital Cost, Net Present Cost and Cost of Electricity in Scenario 1

Dual Fuel Diesel Generator (kW)	*Biomass Generator (kW)*	*Initial Capital Cost ($)*	*Net Present cost ($)*	*Cost of electricity ($/kWh)*
400	0	143333	6722950	0.196
400	100	243333	6797486	0.198

6.2.3.2 Scenario 2

In this case, it is assumed that the agricultural pumping end-use energy requirements need to be met in seven months of the year (i.e. from July to January). In this scenario, the average load for which the system is to be sized will be 9475 kWh/day in the specified months. It is assumed that other parameter such as costs and system sizes remain unchanged. The optimization is again performed to estimate the size of system need to be implemented to meet the specified energy requirements. The results of optimization are presented in the Table 6.3. From the Table 6.3, it can be observed that the 600 kW generator with dual-fire operation should be installed in the region. This system is to be preferred only when the agricultural pumping end-use requirement is distributed seven months in a year.

Table 6.3 Capacity of Dual-Fire Diesel Generator, Biomass Generator, Initial Capital Cost, Net Present Cost and Cost of Electricity in Scenario 2

Dual Fuel Diesel Generator (kW)	*Biomass Generator (kW)*	*Initial Capital Cost ($)*	*Net Present cost ($)*	*Cost of electricity ($/kWh)*
600	0	215000	11816746	0.252
600	100	315000	11891282	0.254

6.2.3.3 Scenario 3

In this scenario, it is assumed that the agricultural load will act for nine months in a year (i.e. from July to March). In this scenario, the average load for which the system is to be sized will be 7370 kWh/day in the specified months. It is assumed that other parameters such as costs and system sizes remain unchanged. The optimization is again performed to estimate the size of system need to be implemented to meet the specified energy requirements. The results of optimization are presented in the Table 6.4. From the Table 6.4, it can be observed that the 500 kW generator with dual-fire operation should be installed in the region. This system is to be preferred only when the agricultural pumping end-use requirement is distributed over nine months in the year.

Table 6.4 Capacity of Dual-Fire Diesel Generator, Biomass Generator, Initial Capital Cost, Net Present Cost and Cost of Electricity in Scenario 3

Dual Fuel Diesel Generator (kW)	*Biomass Generator (kW)*	*Initial Capital Cost ($)*	*Net Present cost ($)*	*Cost of electricity ($/kWh)*
500	0	179167	10359512	0.222
500	100	279167	10434048	0.224

The results of optimization show that the size of the dual-fired diesel generator decreases as the agriculture load is assumed to be distributed over nine months and due to which the cost decreases from 0.252 to 0.222 $/kWh.

6.2.3.4 Scenario Analysis

The scenarios are developed with the assumption of distribution of agricultural pumping end-use energy requirement. It is observed that if scenario 1 is implemented then necessary steps should be taken to distribute the agricultural pumping end-use energy requirement over the year. It is observed during the filed visits that the farming is not carried out throughout the year in all the farms due low water table present in the region (below 300 feets). If scenario 2 is compared with scenario 3, it shows the increase in cost of electricity. It can be noted that higher capacity of generator will increase the cost of electricity. Therefore, based on the cost of electricity incurred in meeting the requirement scenario 3 should be implemented. In scenario 3 dual fired generator of 500 kW capacity is to be selected for implementation.

6.2.3.5 Sensitivity Analyses for Implementation Scenario

The results of sensitivity analysis are shown in Figure 6.5. The sensitivity is provided to the cost of biomass fuel and diesel fuel. The variation in diesel cost is assumed from 0.6 $/lit to 1 $/lit and the variation in cost of biomass fuel is assumed from 40 $/ton to 70 $/ton. The results of sensitivity analysis show that for a lower cost of biomass fuel, the cost of electricity generation is minimum. The cost of electricity in the system depends mainly on cost of diesel fuel. For a fixed value of biomass fuel i.e. 60 $/ton, if the cost of diesel fuel changes from 0.7$/lit to 1$/lit then the cost of electricity changes from 0.222 $/kWh to 0.299 $/kWh.

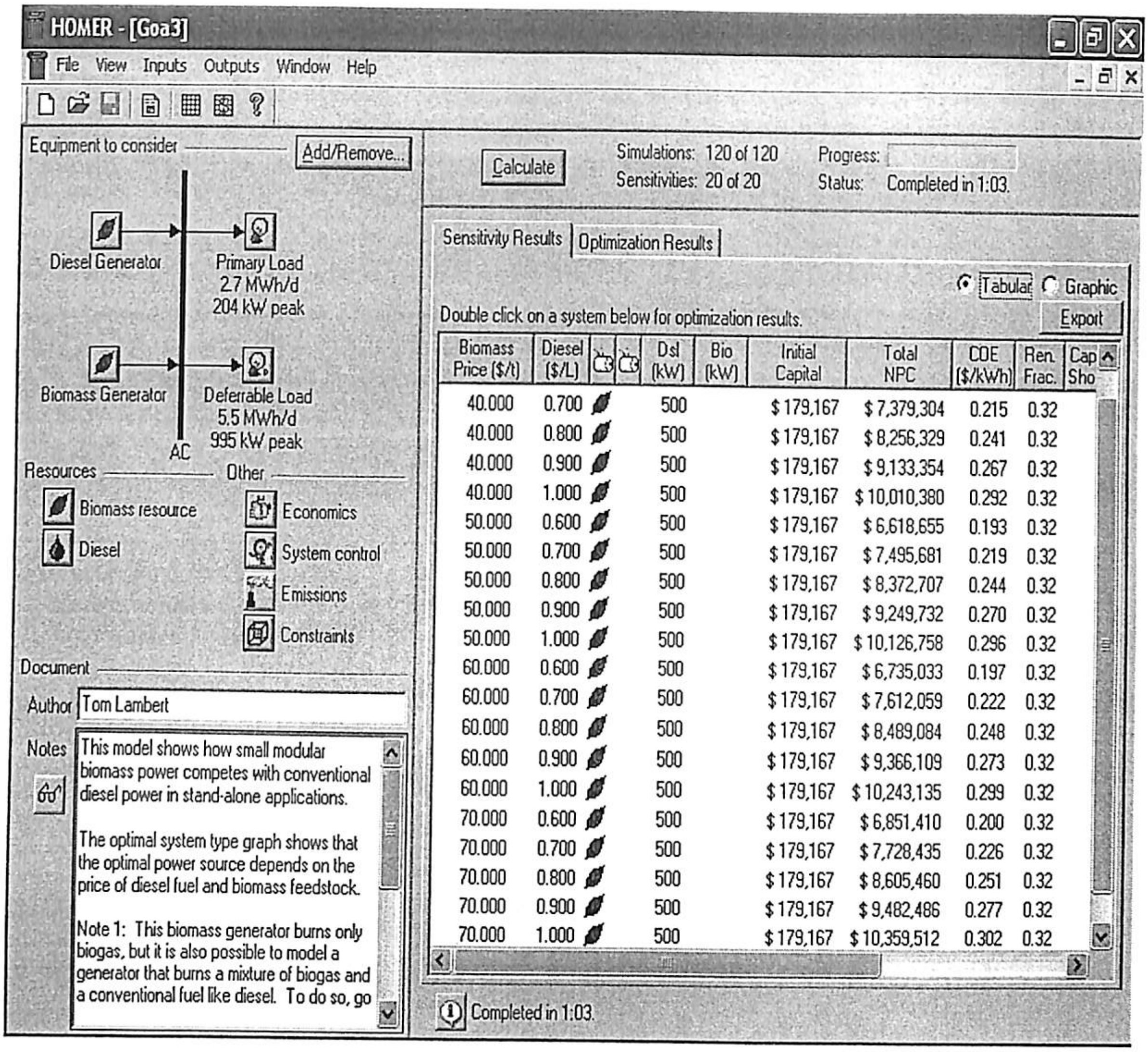

Figure 6.5 Results of Sensitivity Analysis

The results of sensitivity analysis show that the necessary technological modifications are required to make this system to work at the minimum diesel fuel consumption (in this case it is assumed to be 20%). The results of system sizing show that 500 kW dual –fuel diesel generator can be selected for implementation. The actual selection of system is dependent on the technology and system sizes available in India.

6.3 IDENTIFICATION OF BARRIERS FOR ENERGY PLANNING

Planning Commission Government of India launched the IREP in the early 1980s with an objective to meet the basic energy needs of rural people by utilizing local available energy sources. In 1994, the programme was shifted to the MNES. On the implementation side, the program starts with planning at the level of a block of villages, then at the district level and finally at the state level. Figure 6.6 show the traditional roles of stakeholders in existing energy planning and implementation approach.

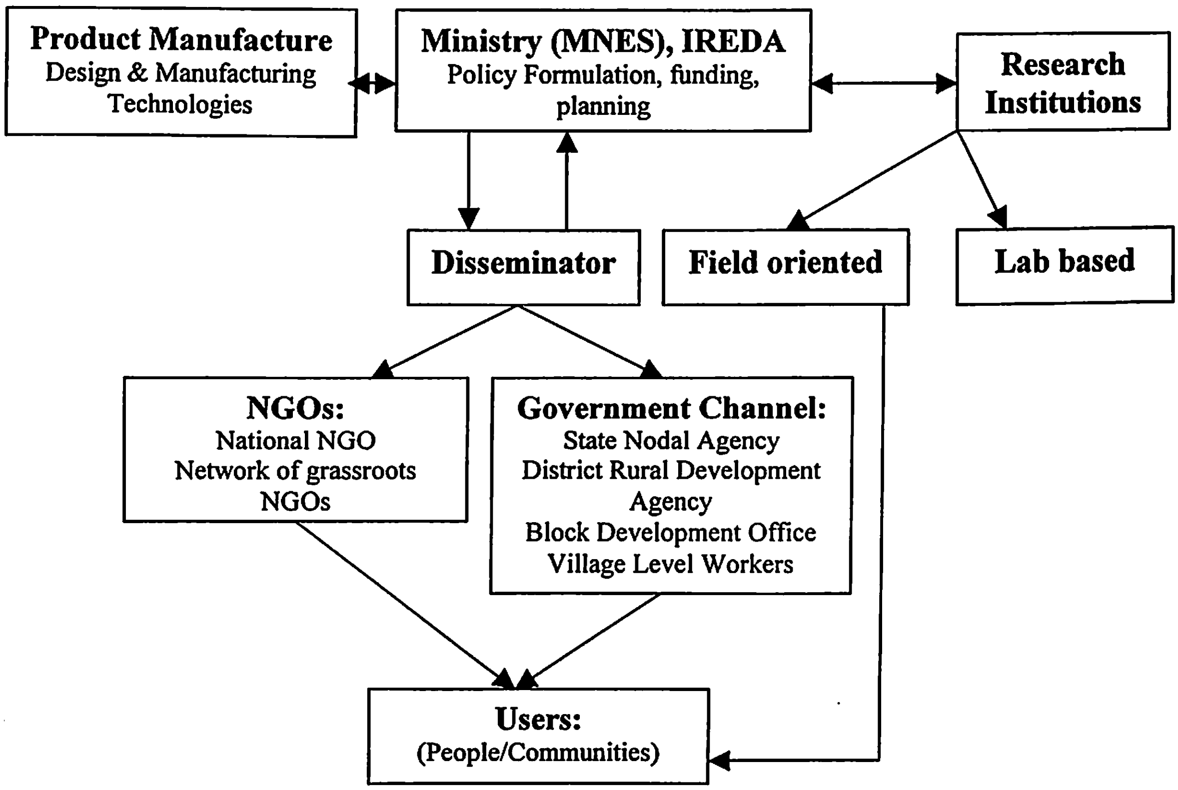

Figure 6.6 Traditional Roles of Stakeholders

Existing planning and implementation approaches which reflect current policy on rural energy lacks local participation (Reddy, 2003, Reddy and Painuly, 2004). The roles of stakeholders are predetermined and there is no analysis of roles and their impact on programme performance. The framework for energy planning for agriculture and rural development can become operational only after overcoming a large number of barriers, problems and constraints, which come in the way of the integration of energy supply programmes with the energy development needs at the local level. These problems and constraints include, lack of mechanisms at the local level to carry out energy planning and assessment with the involvement of the potential beneficiaries, lack of coordination between development programmes and energy supply inputs, which are usually provided as targets imposed from above; lack of trained manpower; lack of coordination between planning, project formulation and implementation. These issues are discussed as follows:

6.3.1 Sectoral and institutional barriers in coordination and top-down flow of targets

The existing approach for planning and implementing energy programmes is top-down and sectoral. Ministry and State Nodal Agencies are considered to be responsible for the supply of different energy resources and programmes in rural areas. These Agencies prepare and implement their own plans and programmes. The targets for these programmes are also imposed from the top-down through uniform directives, or to the district or other administrative agencies at the grassroots level. Moreover, the targets for the different rural energy programmes and options do not have any relationship to one another.

6.3.2 Lack of coordination between energy demand and supply

Rural Development and Agriculture Departments, which are concerned with the development of the agricultural sector and rural areas, usually do not include energy requirements in their programmes (Bhatt and Sachan 2004). This is carried out as a separate activity without sufficiently quantifying the requirements on the basis of regular assessments. As a result of such a sectoral approach, these programmes are planned and implemented separately. These programmes are utilizing significant proportion of the inadequate resources even though the impact at the local level on improving agricultural productivity and bringing about sustainable rural development is marginal.

6.3.3 Lack of people's participation

Lack of impact of the existing energy supply programmes for rural areas is due to the fact that these programmes have been designed without taking into account the needs and priorities of rural people. The assessment of people's needs can, however, only be possible through in-depth micro-level studies and surveys carried out with the active involvement of the rural people. The programmes which are specifically meant for the rural people, e.g. biogas and improved *chulha* programmes, either do not reach them, or are rejected by them because the initial design of the program did not take into account their needs and priorities.

6.3.4 Lack of coordination between Government and voluntary organizations

Government officials in rural areas lack in training or knowledge of energy planning and technology assessment or may not have the motivation to carry out such energy assessment and planning by reaching out to the people. Voluntary action groups and non-governmental organizations, because of their local presence and commitment to rural development, can fill this gap by bringing together the people and the programmes meant for them. However, voluntary agencies and NGOs do not join hands which make a limited impact on improving rural living conditions through sustainable rural development.

6.3.5 Trained manpower

Micro-level energy planning should make the rural people know the importance of energy and its relationship to them and their environment. Trained planners, who can communicate with the rural people and have the professional skills to prepare and implement rural energy plans, are rarely available. Lack of trained manpower has often found to be a major constraint in developing and implementing rural energy planning.

6.3.6 Lack of integration between planning and project formulation and implementation

Rural energy planning becomes useful to rural people, if it is closely integrated with field implementation of rural development programmes, so that they can see projects and activities through which energy technologies and supplies are made available to them to meet their real needs and aspirations. Rural energy plans must therefore result in the formulation and implementation of integrated rural energy projects which are region-wise, and which have the necessary components for the promotion of new technologies and renewable energy sources through appropriate demonstration and extension. The design and components of such region-wise integrated rural energy programmes and projects have to be prepared and coordinated with other rural development.

In summary, the framework for rural energy planning can become operational and effective only after the problems and constraints, which are related to mechanisms to ensure local participation, and the institutional set up and coordination mechanisms at the national, state and local levels is to be designed and developed.

6.4 RECOMMENDED MECHANISM FOR OVERCOMING THE BARRIERS

The development of a rural energy plan is only the first step in the intervention IRES development process. The implementation of the plan into a viable program for action is a non trivial task. The implementation approach used for any project will also need to be customized to take into consideration of the local social culture-economic context.

6.4.1 Redefining Roles

A participatory implementation approach means that the roles of the stakeholders will potentially differ from locality to locality, even within the same program. It is possible and necessary nonetheless to define a more effective general model for the role for stakeholders. In a decentralized framework, NGO, with their local presence should be significantly involved in the rural energy development process. Ideally, NGO have to adopt the role of facilitator of rural energy programmes, providing the technical and logistical support. The local people will adopt the role of hands-on planners and implementing team as shown in Figure 6.7.

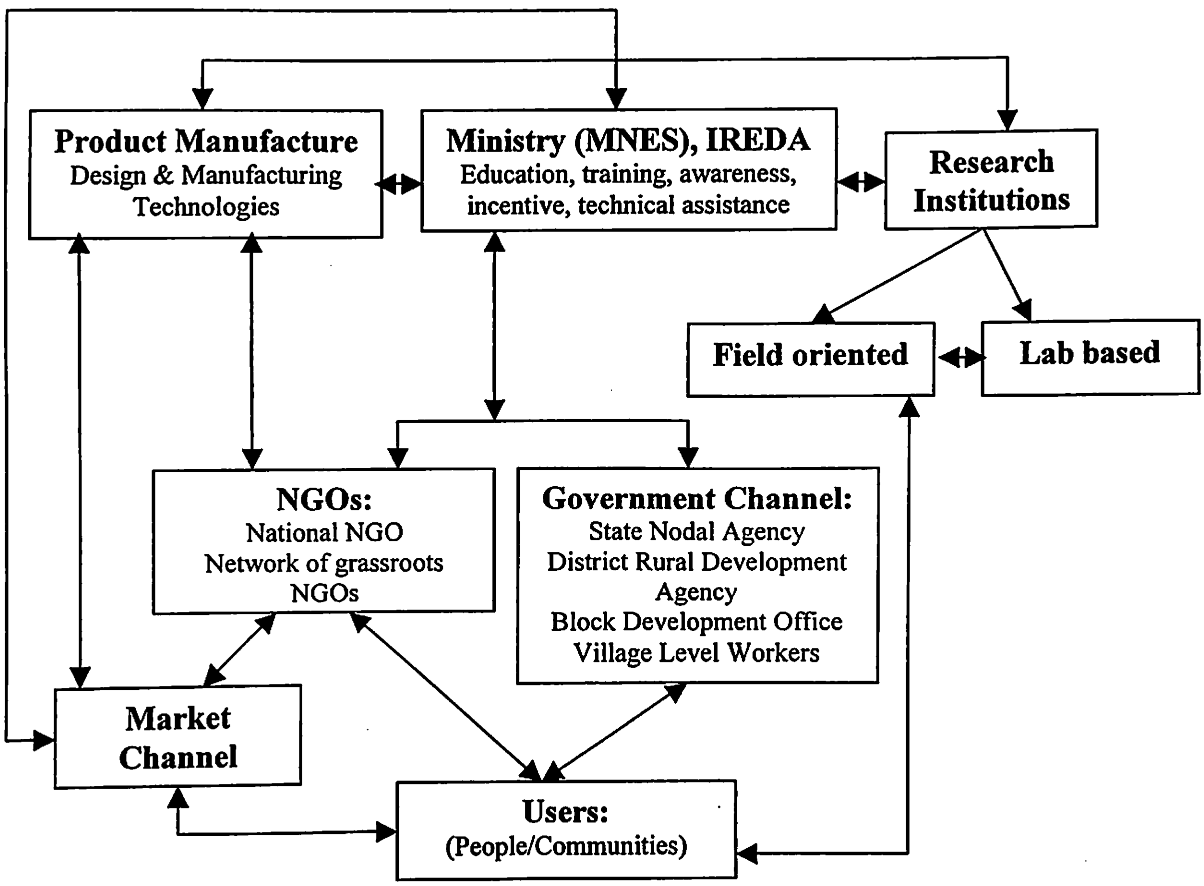

Figure 6.7 Suggested Model for New Stakeholders Role

6.4.2 Multiple Delivery Mechanisms

To give rural people access to the widest range of financially and technically sound technologies and options, a market approach is needed to achieve the wide scale dissemination of renewable energy technologies. This in-turn requires considerable efforts in product development.

6.4.3 Perceptional Change

Local communities should not be viewed as targeted beneficiaries, but as partners in the development process. When local community is actively involved in programme planning, they are provided with an opportunity to articulate not only their felt needs, but also their willingness to participate and the level and type of benefits they require and commitment.

6.4.4 Participation of Women

A corollary to the need for local participation is the need for genuine participation of local women. In the domestic sector in rural India, a woman takes the role of the producer, procurer, and manager of energy. The success of energy interventions rests significantly on the contribution of knowledge and expertise by the local women. However, social and cultural norms in rural India often preclude the participation of women in activities outside home. While remaining sensitive to local traditions, implementation schemes need to not only reach to local women but also include mechanisms for facilitating their genuine participation in the implementation process.

To be able to effectively tackle the many pressing rural issues exist today, a comprehensive, overarching vision or policy on rural energy must be articulated. Without adequate national level policy changes, the recommendations for decentralized and participatory planning and implementation will be difficult to realize. At the national level, decentralized and participatory approaches for all rural energy projects and programmes needs to be adopted as a general policy.

Policy makers and planners will not be able to shift from their traditional centralized, target-based, technology-driven and top-down approach without adequate awareness of and sensitivity to the need for a decentralized and participatory approach and sensitivity to the real needs of rural people, especially women. Policy makers need to be sensitized to:

1. Regional energy planning should be carried out by local populace. There is need for incorporation of local knowledge and expertise in designing decentralized IRES plans;

2. ensuring continuity of peoples participation ; and

3. development of local capacities and tasks of programme planning, implementation, supervision, and maintenance of IRES.

To allow rural people to plan and implement rural energy development programmes, policies that support and facilitate local capacity building are needed. In this area, government policies are needed that develop and support adult education programmes to provide people with skills needed for locally empowered development.

The next chapter presents the summary of results and conclusion of the study. The chapter also presents specific contributions and further scope of work.

Chapter 7: Results and Conclusions

In this chapter, summary of results and conclusions of the research work are presented. The salient features of the work are highlighted. Scope for further work is also presented.

7.1. SUMMARY OF RESULTS

In the study, variation is observed in the secondary data available with the government offices and primary data collected through the survey for *Panthadiya, Bisanpura 1st*, *Bisanpura 2nd*, and *Morva* villages. The secondary data is compiled over a period of several years and is not updated. Due to which the secondary data cannot be used for energy estimation. The survey was carried out for six different end-uses, namely, cooking, lighting, pumping, heating, cooling and appliances. The results of primary survey based on the landholding category shows that maximum per capita energy consumption for all the end-uses is observed in large and very large farmers followed by medium, small farmers and landless in all the surveyed villages. The results of survey for *Panthadiya* villages show that cooking end-use contributes for maximum (47%) followed by pumping end-use (41%), cooling end-use (7%), lighting end-use (3%) and appliance end-use (2%) of the total energy requirement of the village. The energy consumption for heating end-use is observed to be minimum due to the hot climatic conditions of the region. Household energy consumption pattern for *Panthadiya* village show that cooking end use accounted for 81% of total energy requirement. The per capita cooking energy consumption in *Panthadiya* village is observed to be 1.44 kWh/day, due to the use of low efficiency device (*Chulha*). In the primary survey for *Panthadiya* village, it is observed that 43% of the households belong to the medium farmer category (1 to 2.5 ha). The population distribution pattern and operational landholding show that 43% of the land is owned by medium farmers. The results of survey show that the *Panthadiya* village has higher potential of biogas energy source due to higher cattle to population ratio (0.5).

The energy needs of the region and available unutilized energy resource are used to define a region. The energy plans are developed to fulfill the objective of meeting energy requirements subject to certain limit or constraints. These constraints correspond to resource availability, technology options, cost of utilization, environmental impact, socio-economic impact, employment generation, at present as well as in future. The objective of energy plans for the new region are related to socio-economic development.

The results of optimal energy resource allocation for *Panthadiya* village, when all the objectives are given equal priority show that, the cost associated with the scenario increases many folds compared to that of the present cost of energy consumption. The associated emissions in the equal priority scenario decreases by 57%, 99% and 88% for CO_x, SO_x and NO_x respectively. The results of optimization reveal that the associated cost increases by 2.8%, when environment emissions are given a higher priority, due to the present higher costs. When employment generation is given a higher priority in economic objectives, the results show that the cost is increased by 7.5% and associated emissions are reduced. The study shows that the associated cost and environment emissions can be reduced by cost-employment generation scenario. The scenario results in cost reduction by 5.9% of present cost of energy utilization and reduction of 62.23% and 90.83% in CO_x, and NO_x, emissions respectively, but increases SO_x emissions by 87.69% due to the allocation of biogas for cooking end-use. Due to the use of local energy resources, the scenario satisfies the goal of employment generation at the reduction of environment emissions. Cost-employment generation scenario shows that 10% of biomass energy remains unutilized and dung cake energy is not allocated in optimal energy resource allocation. In order to expedite development of IRES, the unutilized energy resource can be diverted to energy resource allocation in inter village-mix.

The inter village-mix is decided on the basis of scope for renewable energy utilization in IRES development. The results of optimal energy resource allocation in neighboring villages such as *Bisanpura 1st*, *Bisanpura 2nd*, and *Morva*, shows that in all the villages, there is scope for utilization of renewable energy resource utilization. The results of optimal energy resource allocation shows that dung cake (100%) is not allocated in any inter village-mix. Biomass energy resource 11.42%, 11.95%, 10.53%, 11.08%, 11.89% and 11.86% is not allocated in optimal scenario for *Panthadiya-Bisanpura 1st*, *Panthadiya-Bisanpura 2nd*, *Panthadiya-Morva*, *Panthadiya-Bisanpura 1st-Bisanpura 2nd*, *Panthadiya-Bisanpura 1st –Morva*, *Panthadiya-Bisanpura 2nd-Morva* and *Panthadiya-Bisanpura 1st-Bisanpura 2nd-Morva* village-mix respectively. The dung cake energy resource is not allocated for cooking end-use due to its higher associated emissions (0.633 kg/kWh, 0.0013 kg/kWh and 1.709 x 10^{-2} kg/kWh for Carbon, Sulphur and Nitrogen respectively). The biomass energy is abundant in excess of energy needs. The results of village-mix show that *Panthadiya-Bisanpura 2nd* village has maximum unutilized local energy potential. Therefore, *Panthadiya-Bisanpura 2nd* village is identified as a region for energy planning.

Short-term (for 2010-11) and medium-term (2015-16) scenarios are developed for the region, namely, base case scenario, biogas scenario, and biomass energy scenario. In the base case scenario, it is assumed that the energy resource availability will remain unchanged as that of the base year. In biogas scenario, 20% growth rate is assumed in cattle to population ratio. In biomass energy scenario, 20% increase in firewood is assumed. In short term energy planning, plans are developed for minimum cost of energy utilization, maximum employment generation and maximum use of local resource. In medium term planning, plans are developed for minimum cost of energy utilization, maximum employment generation, maximum use of local resource and minimum environment emissions.

The results of short-term scenario reveal that for faster realization of IRES, base case scenario should be implemented. In all the short term scenarios, it is observed that biomass electricity is allocated to lighting, pumping, cooling and appliance end-use due to the high employment generation potential at the lower costs. For cooking end-use biogas, LPG and solar thermal energy is to be allocated. The percentage allocation of LPG decreases by 20%, when biogas scenario is preferred over base case scenario. In the base case scenario, optimal energy resource allocation is carried out with respect to present energy resource availability and resulted in 35% non utilization of biomass energy resource. In the scenario dung cake is not allocated for cooking end-use, therefore the same energy can be diverted to biogas energy resource. The biogas scenario should be implemented only when the expected growth rate of 20% in cattle to population is observed. The biomass energy scenario should to be implemented only when the expected growth rate in biomass energy is achieved.

The results of medium-term scenarios, namely, base-case, biogas, and biomass energy scenario shows that biomass (10 to 17%) is to be allocated for cooking end-use due to which biomass energy is completely utilized for energy resource allocations. The objectives set for medium term planning can be met in short term planning, therefore short term planning should be preferred over medium term planning and necessary steps should be taken to achieve the objectives of medium term planning. Moreover, the realization of IRES development can be observed by implementing biogas energy scenario.

The energy resource allocation in biogas energy scenario for short-term planning in the region reveals that LPG, biogas and solar thermal should be promoted for cooking, and solar thermal for heating end-use. LPG (31.04%) is to be allocated for cooking due to the constraint of biogas and biomass energy resource potential and is preferred over dung cake due to the lower associated emissions and higher system efficiency. Biomass electricity is to be promoted for lighting, pumping, cooling, and appliance end-uses due to their high employment generation potential at the lower costs. The cost associated with biogas energy scenario is Rs. 10.97 millions and the associated emissions are 1333.97, 1.84, 58.20 Tons/year for CO_x, NO_x and SO_x, respectively.

For implementation of energy plan, it is essential to estimate the size of power generating system, which will make plan feasible. The present study estimates the required capacity of power generating capacities required to fulfill the energy requirements of the region.

Different scenarios are developed with the assumption of the distribution of agricultural pumping end-use energy requirement to size the system using HOMER software. It is observed that the cost of electricity in scenario 1 is lower than the other scenarios, wherein necessary steps should be taken to distribute the agricultural pumping end-use energy requirement over the year. When scenario 2 is compared with scenario 3, it shows the increase in cost of electricity. It is observed that higher capacity of generator will increase the cost of electricity. Therefore, based on the cost of electricity incurred in meeting the requirement scenario 3 is recommended for implementation. In scenario 3 dual fired generator of 500 kW capacity is recommended for implementation. The results of sensitivity analysis show that if the cost of biomass fuel and diesel fuel increases from present costs then for a lower cost of biomass fuel, the cost of electricity generation is minimum. The results of optimization show that in the recommended system, cost of electricity in the system depends mainly on cost of diesel fuel. For a fixed value of biomass fuel i.e. 60 \$/Ton, if the cost of diesel fuel increases from 0.7\$/lit to 1\$/lit then the cost of electricity increases from 0.222 \$/kWh to 0.299 \$/kWh.

In order to implement energy plan in existing framework of energy planning, there is need to redefine the role of stakeholders. To be able to effectively tackle the many pressing rural issues exist today, a comprehensive, overarching vision or policy on rural energy must be articulated. For these reasons decentralized and participatory planning and implementation is recommended. Policy makers and planners will now have to shift focus from their traditional centralized, target-based, technology-driven and top-down approach to the decentralized approach recommended here, which typifies participatory approach that is sensitive to the real needs of rural people, especially women.

7.2. CONCLUSIONS

In the work reported, new approach for defining region for energy planning has been adopted. First, energy survey of village is conducted to estimate energy resource availability and requirement. Next, using the results of survey, optimal energy scenario has been generated. It is found that, if the optimal energy scenario is implemented fully, substantial amount of energy resource will remain unutilized, which may be utilized for meeting energy needs in neighboring villages. For the purpose of generating optimal energy scenario for the region, consisting of group of villages, a region for energy planning is required to be defined. The options for defining region, consisting of group of villages have been searched from among the possible combinations of villages.

The technique of goal programming, which has been usually used for macro level energy planning, has been adopted for generating optimal energy scenarios for the region so defined. Thus optimization is carried out with respect to ten objective functions and ten constraints. The results show that by redefining region for inclusion of sufficient number of villages for maximum utilization of available energy resources, the development of IRES for power generation can be expedited. It is shown that biomass and bio energy are available for effecting inter village mix of resources for maximizing utilization.

On one hand, the speed of implementation of optimal scenario will be decided by economic, environmental and socio-economic benefits to be accrued and; the existing technical and socio-economic barriers in the region. The existing barriers can be overcome only in the long run through conscious efforts on the part of ministry, SNAs and local panchayats for education, awareness, promotion, planning, implementation, training, technical assistance, and participation. The results of work reported here will generate confidence among the energy planners committed for development of IRES.

7.3. SPECIFIC CONTRIBUTIONS

Specific contributions of the study are:

1. The thesis is about an attempt to redefine traditional approach to micro level energy planning process. In the present work results are obtained using technique of goal programming applied to micro level planning. The technique of goal programming is normally used for energy planning at macro level.
2. In the present work, results of survey for four villages located in northern parts of Rajasthan have been presented. These results have been used to redefine region for energy planning at micro level by considering different combinations of villages.

3. Micro-level energy planning in the region for ten different objective functions is carried out as in the case of macro-level energy planning.

4. Optimum size of IRES based power generating system for the region is determined.

5. An appropriate participatory approach for implementation of recommended energy plan for the newly defined region is also described.

7.4. FURTHER SCOPE OF WORK

The methodology described in the present work can also be adapted to other regions, having range of available local energy resources and end-use-resource applications; new regions can be defined for micro-level energy planning. Fuzzy evaluation techniques may also be applied to tackle uncertainties for volume of data used in energy planning process. Comprehensive appropriate tool useful for region-wise development of IRES may be developed.

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Appendix I:

Primary Questionnaire for defining a region for Integrated Renewable Energy System

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Name of the Village: ______________________________

Part A: Demographic Information

Name: ____

Age: _________ Years

Part B: Specific Information

1. Members in the house:

   Seniors: ☐ Male: ☐ Female: ☐ kids: ☐

2. Number of cattle in the house: ☐

3. Cow dung available per cattle: ____ kg (Approximately)

4. Cow dung used for dung cakes:_____% (Approximately)

5. Biomass required by the house is available in the region: Yes/No

   If "No" then ____ % purchased from outside the region

6. Land available with the house: _______________ (Acre)

7. Availability of conventional electricity supply: _____ hrs

Part C: Questionnaire for Energy Requirements of the House

1. Cooking Energy Requirements:

a. Amount of biomass consumed per day: __________ kg (approximately)

b. Amount of dung cake consumed per day: __________ kg (approximately)

c. Time duration for consuming one LPG cylinder: _________ days

2. Lighting Energy Requirements:

a. Wattage of tube light **40 W**, Number of tube lights ☐, usage period ____ hrs

b. Wattage of incandescent bulb **100 W**, No. of incandescent bulb ☐, usage period _ hrs

c. Wattage of incandescent bulb **60 W**, No. of incandescent bulb ☐, usage period __hrs

d. Wattage of incandescent bulb **40 W**, No. of incandescent bulb ☐, usage period __ hrs

e. Wattage of incandescent bulb **15 W**, No. of incandescent bulb ☐, usage period __ hrs

f. Amount of kerosene consumed per day: __________ liters (approximately)

3. Pumping Energy Requirements:

a. Wattage of pump _____ W, Number of pumps ☐, usage period ____ hrs

4. Heating Energy Requirements:

a. Wattage of geyser/electric rod _____W, Number of geyser/electric rod ☐, usage period __hrs

b. Wattage of convective air heater _____W, Number of blower ☐, usage period ___ hrs

c. Amount of biomass consumed per day: __________ kg (approximately)

5. Cooling Energy Requirements:

a. Wattage of fan **60 W**, Number of fans ☐, usage period ____ hrs

b. Wattage of air cooler **170 W**, Number of air coolers ☐, usage period ____ hrs

c. Wattage of refrigerator **225 W**, Number of refrigerator ☐, usage period ____ hrs

6. Appliances Energy Requirements:

a. Wattage of television **100 W**, Number of television ☐, usage period ____ hrs

b. Wattage of music system **50 W**, Number of music system ☐, usage period ____hrs

c. Wattage of mixer **450 W**, Number of mixer ☐, usage period ____ hrs

e. Wattage of curd churner **300 W**, Number of curd churner ☐, usage period ____hrs

f. Wattage of washing m/c **300 W**, Number of washing m/c ☐, usage period ____hrs

g. Wattage of computer **150 W**, Number of computer ☐, usage period ____hrs

d. Wattage of any other appliance ___W, Number of appliances ☐, usage period__ hrs

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
1	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0857
2	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0857
3	4	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0000
4	2	0	1	1	0	1	5	2	0	0	1	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.76	0.09	0.0002	0.0000	0.0000
5	1	0	1	0	0	0	3	1	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	2.13	0.12	0.0002	0.0000	0.0000
6	4	0	1	1	2	0	5	2	75	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.04	0.0002	0.1286	0.0857
7	5	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.04	0.0002	0.1091	0.0727
8	4	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.04	0.0002	0.1286	0.0857
9	6	0	1	1	4	0	7	2	75	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.56	0.03	0.0002	0.0947	0.0000
10	7	0	3	3	1	0	12	2	0	0	1	0	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.20	0.03	0.0002	0.0610	0.0407
11	8	0	4	4	0	3	15	2	0	0	1	0	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.03	0.02	0.0002	0.0436	0.0291
12	5	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.0000	0.0000
13	11	0	5	3	3	0	15	1	30	0	1	2	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.22	0.05	0.0002	0.0404	0.0270
14	4	0	1	1	2	0	5	1	75	0	0	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.53	0.04	0.0002	0.1286	0.0000
15	4	0	1	1	2	0	5	1	75	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.53	0.04	0.0002	0.0000	0.0000
16	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.80	0.10	0.0002	0.7236	0.1114
17	5	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.04	0.0002	0.1091	0.0727
18	6	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0000
19	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0857
20	3	0	1	1	1	0	5	2	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.64	0.05	0.0002	0.0000	0.0000
21	6	1	3	0	2	0	10	1	45	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.55	0.09	0.0002	0.0750	0.0500
22	4	0	1	1	2	0	6	2	75	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.95	0.04	0.0002	0.1286	0.0857

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
23	4	0	1	1	2	0	6	2	75	0	0	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.95	0.04	0.0002	0.1286	0.0000
24	6	0	1	1	4	0	8	2	75	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.69	0.03	0.0002	0.0947	0.0000
25	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	2	1	1	1	1	1	0	0	0	0	1.80	0.10	0.0002	0.8327	0.1114
26	4	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.78	0.11	0.0002	0.1286	0.0000
27	2	0	1	1	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	2	0	0	1	0	0	0	0	0	0	2.10	0.18	0.0002	0.4000	0.1333
28	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.10	0.0002	0.1091	0.0727
29	4	0	3	1	0	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.08	0.0002	0.0947	0.0632
30	6	0	1	1	4	0	8	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.37	0.03	0.0002	0.0947	0.0000
31	2	0	1	1	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.71	0.11	0.0002	0.2000	0.1333
32	4	0	1	1	2	0	5	2	75	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.78	0.04	0.0002	0.0000	0.0000
33	4	0	1	1	2	0	5	2	75	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.78	0.04	0.0002	0.0000	0.0000
34	4	0	3	1	0	0	8	2	60	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.76	0.03	0.0002	0.0947	0.0632
35	6	0	2	2	2	1	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.06	0.0002	0.0727	0.0485
36	6	0	4	1	1	0	10	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.16	0.06	0.0002	0.0679	0.0453
37	5	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0727
38	5	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0727
39	7	0	1	1	5	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.10	0.03	0.0002	0.0837	0.0558
40	8	1	1	1	5	0	10	2	0	0	0	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.20	0.02	0.0002	0.0706	0.0471
41	7	0	1	1	5	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.10	0.03	0.0002	0.0837	0.0558
42	6	0	1	1	4	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.12	0.0002	0.0947	0.0632
43	4	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0000
44	3	1	1	1	0	0	5	2	60	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	2.03	0.12	0.0002	0.1385	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
45	4	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.11	0.0002	0.1286	0.0857
46	4	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.11	0.0002	0.1286	0.0857
47	2	0	1	1	0	1	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.99	0.15	0.0002	0.1674	0.1116
48	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.07	0.0002	0.0000	0.0000
49	6	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0632
50	7	0	2	3	2	0	10	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.14	0.06	0.0002	0.0667	0.0444
51	4	0	4	0	0	0	8	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.68	0.08	0.0002	0.0900	0.0600
52	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.10	0.0002	0.1091	0.0727
53	6	1	1	1	3	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.27	0.08	0.0002	0.0878	0.0585
54	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.10	0.0002	0.1091	0.0727
55	6	0	2	1	3	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.21	0.07	0.0002	0.0837	0.0558
56	4	0	1	1	2	0	5	2	75	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.16	0.0002	0.1286	0.0857
57	3	0	2	1	0	0	5	2	0	0	1	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.07	0.0002	0.0000	0.0000
58	2	0	1	1	0	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	2.77	0.18	0.0002	1.3267	0.2042
59	6	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.05	0.0002	0.0947	0.0632
60	5	0	3	2	0	0	10	1	45	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	0	0	0	0	1.62	0.10	0.0002	0.1565	0.0522
61	5	0	3	2	0	3	12	2	0	0	1	1	0	0	0.05	0	0	3	2	0	0	1	0	0	0	0	0	0	1.25	0.06	0.0002	0.1274	0.0425
62	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.10	0.0002	0.1091	0.0727
63	6	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.05	0.0002	0.0947	0.0632
64	2	0	1	1	0	1	5	2	75	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	2.32	0.09	0.0002	0.1674	0.1116
65	1	0	1	0	0	0	3	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	2.13	0.32	0.0002	0.3600	0.0000
66	5	1	1	1	2	0	7	2	60	0	2	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.73	0.21	0.0002	0.1000	0.0667

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
67	7	0	1	3	3	0	10	2	60	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.56	0.02	0.0002	0.0000	0.0000
68	5	0	1	1	3	0	5	2	0	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.14	0.04	0.0002	0.0000	0.0000
69	7	2	1	1	3	0	10	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.56	0.07	0.0002	0.0735	0.0000
70	4	0	1	1	2	0	5	2	75	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.78	0.04	0.0002	0.0000	0.0000
71	3	0	1	1	1	0	5	2	0	0	0	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.64	0.05	0.0002	0.1565	0.0000
72	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0000
73	7	1	2	1	3	0	10	2	0	0	1	0	0	0	0.05	0	0	3	1	0	0	0	0	0	0	0	0	0	1.20	0.04	0.0002	0.0706	0.0000
74	11	1	4	3	3	0	15	1	30	1	1	4	0	0	0.05	0	0	4	6	1	1	1	1	1	1	0	0	0	1.24	0.09	0.0002	0.4814	0.0474
75	2	2	0	0	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.92	0.13	0.0002	0.2250	0.0000
76	4	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.11	0.0002	0.1286	0.0857
77	3	0	1	1	1	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.64	0.09	0.0002	0.1565	0.0000
78	4	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0857
79	4	0	3	1	0	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.12	0.0002	0.0947	0.0632
80	4	0	3	1	0	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0632
81	2	0	1	1	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	2.10	0.18	0.0002	0.2000	0.1333
82	4	0	2	2	0	0	7	2	0	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.31	0.03	0.0002	0.0000	0.0000
83	6	0	2	4	0	0	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.18	0.08	0.0002	0.0692	0.0462
84	6	0	5	1	0	0	12	1	45	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.45	0.08	0.0002	0.0621	'0.0414
85	6	0	4	2	0	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.26	0.06	0.0002	0.0643	0.0429
86	4	0	3	1	0	0	8	2	0	0	1	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.37	0.05	0.0002	0.0000	0.0000
87	12	2	3	3	4	0	15	1	30	0	1	2	0	0	0.05	0	0	5	1	0	0	1	0	0	0	0	0	0	1.20	0.05	0.0002	0.0400	0.0267
88	6	0	4	2	0	0	12	1	45	0	1	1	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.50	0.06	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
89	6	1	2	2	1	0	10	1	45	0	1	1	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.52	0.07	0.0002	0.4873	0.0750
90	2	2	0	0	0	0	2	0	75	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.20	0.0002	0.2250	0.0000
91	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.80	0.10	0.0002	0.0000	0.0000
92	5	0	3	1	1	0	7	2	60	1	2	2	0	0	0.05	0	0	2	3	0	0	1	0	0	1	0	0	0	1.45	0.17	0.0002	0.2512	0.0663
93	5	0	3	2	0	3	12	1	45	1	1	3	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.49	0.12	0.0002	0.4864	0.0730
94	6	0	3	1	2	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.28	0.07	0.0002	0.0750	0.0594
95	3	0	1	1	1	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.64	0.09	0.0002	0.1565	0.1239
96	5	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.10	0.0002	0.1091	0.0864
97	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.07	0.0002	0.1286	0.1018
98	2	0	1	1	0	0	5	1	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.07	0.0002	0.0000	0.0000
99	5	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.04	0.0002	0.0000	0.0000
100	5	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.80	0.10	0.0002	0.1091	0.0864
101	4	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.35	0.11	0.0002	0.8529	0.1473
102	3	0	1	1	1	1	5	2	75	0	1	2	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.88	0.17	0.0002	0.9011	0.1557
103	5	1	1	1	2	0	7	2	60	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.73	0.03	0.0002	0.0000	0.0000
104	6	0	2	2	2	0	10	2	60	1	1	3	0	0	0.05	0	0	2	5	1	1	1	1	1	1	0	0	0	1.66	0.14	0.0002	0.8322	0.0897
105	8	0	3	3	2	0	12	2	0	0	1	0	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.11	0.03	0.0002	0.0563	0.0375
106	3	0	2	1	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.11	0.0002	0.1286	0.1018
107	8	2	1	1	4	0	10	2	60	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.42	0.06	0.0002	0.0667	0.0528
108	4	0	2	1	1	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.04	0.0002	0.1091	0.0000
109	4	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.04	0.0002	0.0000	0.0000
110	6	1	1	2	2	0	8	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.18	0.03	0.0002	0.0818	0.0545

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
111	7	0	3	2	2	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.26	0.06	0.0002	0.0643	0.0429
112	7	0	4	2	1	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.16	0.05	0.0002	0.0590	0.0393
113	6	0	4	2	0	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.26	0.06	0.0002	0.0643	0.0429
114	5	0	1	2	2	0	7	2	60	0	1	1	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.73	0.09	0.0002	0.7633	0.1146
115	5	0	2	2	1	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.08	0.0002	0.0878	0.0695
116	9	0	3	3	3	0	15	1	45	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.42	0.05	0.0002	0.0522	0.0413
117	9	0	3	3	3	1	15	1	45	2	2	4	0	0	0.05	0	0	4	2	1	1	1	1	1	1	0	0	0	1.35	0.15	0.0002	0.3790	0.0569
118	2	0	1	1	0	0	5	1	75	1	1	3	0	0	0.05	0	0	1	2	0	0	1	0	0	1	0	0	0	2.38	0.36	0.0002	0.4000	0.1583
119	6	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.05	0.0002	0.0947	0.0750
120	4	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.07	0.0002	0.1286	0.1018
121	5	0	3	1	1	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.07	0.0002	0.0837	0.0663
122	3	0	2	1	0	0	5	2	60	1	1	3	0	0	0.05	0	0	1	1	1	0	1	0	0	1	0	0	0	1.89	0.23	0.0002	0.2743	0.1018
123	7	0	3	4	0	1	10	1	30	1	1	3	0	0	0.05	0	0	3	3	1	0	1	0	0	1	0	0	0	1.29	0.10	0.0002	0.2272	0.0435
124	6	0	3	3	0	0	10	1	45	0	1	2	0	0	0.05	0	0	3	2	0	0	1	0	0	1	0	0	0	1.38	0.08	0.0002	0.1333	0.0528
125	3	0	0	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	2	1	0	1	0	0	1	0	0	0	2.77	0.31	0.0002	0.6267	0.1583
126	6	1	0	2	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.21	0.11	0.0002	0.0923	0.0731
127	11	1	2	2	6	0	15	2	0	0	1	3	0	0	0.05	0	0	4	2	0	0	1	0	0	1	0	0	0	1.15	0.08	0.0002	0.0973	0.0385
128	10	1	3	2	4	0	15	1	45	1	1	3	0	0	0.05	0	0	4	2	1	0	1	0	0	1	0	0	0	1.33	0.09	0.0002	0.1524	0.0385
129	4	0	2	1	1	0	7	2	0	0	1	1	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.43	0.10	0.0002	0.2182	0.0864
130	6	0	3	1	2	0	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.28	0.09	0.0002	0.0750	0.0594
131	6	0	2	1	3	0	8	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.07	0.0002	0.0837	0.0663
132	6	0	2	1	3	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.21	0.10	0.0002	0.0837	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
133	2	1	1	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.71	0.18	0.0002	0.2000	0.0000
134	6	0	5	1	0	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.22	0.06	0.0002	0.0621	0.0491
135	7	1	1	1	4	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.33	0.07	0.0002	0.0783	0.0098
136	10	1	2	3	4	0	15	1	45	1	1	4	0	0	0.05	0	0	4	5	1	1	1	1	1	1	0	0	0	1.36	0.11	0.0002	0.5317	0.0573
137	5	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	2	1	0	1	0	0	1	0	0	0	1.80	0.20	0.0002	0.3418	0.0864
138	5	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0864
139	4	1	1	1	1	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	2.01	0.14	0.0002	0.7703	0.1331
140	11	0	3	4	4	0	15	1	30	0	1	2	0	0	0.05	0	0	4	3	1	0	1	0	0	1	0	0	0	1.32	0.05	0.0002	0.1815	0.0348
141	4	0	3	1	0	0	8	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.76	0.08	0.0002	0.0947	0.0000
142	5	1	1	1	2	0	7	2	60	0	1	1	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.73	0.09	0.0002	0.2000	0.0792
143	2	0	1	1	0	0	5	2	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	2.10	0.07	0.0002	0.0000	0.0000
144	3	0	1	2	0	0	5	2	60	0	0	1	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	2.03	0.05	0.0002	0.1385	0.0173
145	4	0	3	1	0	0	8	2	0	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.37	0.03	0.0002	0.0000	0.0000
146	6	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.08	0.0002	0.0947	0.0118
147	5	2	2	1	0	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.07	0.10	0.0002	0.0818	0.0648
148	5	2	1	1	1	0	8	2	0	0	1	2	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.33	0.11	0.0002	0.7046	0.1058
149	11	2	3	3	3	0	15	1	30	1	1	4	0	0	0.05	0	0	4	4	1	1	1	1	1	1	0	0	0	1.27	0.09	0.0002	0.4080	0.0485
150	4	0	3	1	0	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.37	0.08	0.0002	0.0947	0.0000
151	1	0	1	0	0	0	3	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	2.13	0.20	0.0002	0.3600	0.0000
152	6	1	1	1	3	0	8	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.27	0.05	0.0002	0.0878	0.0585
153	10	0	4	3	3	0	15	2	0	0	1	2	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.08	0.06	0.0002	0.0456	0.0304
154	6	1	2	2	1	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.25	0.07	0.0002	0.0735	0.0490

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
155	13	1	4	3	5	0	15	2	0	0	1	1	0	0	0.05	0	0	5	1	0	0	1	0	0	1	0	0	0	0.88	0.03	0.0002	0.0371	0.0294
156	4	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.04	0.0002	0.0000	0.0000
157	7	1	1	1	4	0	10	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.33	0.04	0.0002	0.0783	0.0098
158	7	2	1	1	3	0	10	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.09	0.0002	0.0735	0.0582
159	5	0	2	1	2	0	8	2	60	0	1	2	0	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.76	0.12	0.0002	0.8179	0.1086
160	4	0	2	2	0	1	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.32	0.11	0.0002	0.0911	0.0722
161	4	0	2	1	1	0	7	2	60	0	1	2	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.89	0.13	0.0002	0.0000	0.0000
162	4	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.78	0.11	0.0002	0.0000	0.0000
163	5	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.10	0.0002	0.1091	0.0864
164	4	1	1	2	0	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.39	0.09	0.0002	0.1059	0.0132
165	9	0	4	3	2	0	15	2	0	0	1	1	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.15	0.04	0.0002	0.0486	0.0385
166	10	2	2	2	4	0	15	2	0	0	1	1	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.18	0.04	0.0002	0.0500	0.0396
167	5	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.04	0.0002	0.1091	0.0864
168	4	2	1	1	0	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.39	0.09	0.0002	0.1059	0.0838
169	10	0	1	1	8	0	12	2	60	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.48	0.06	0.0002	0.0621	0.0491
170	10	2	3	2	3	0	12	1	30	1	1	3	0	0	0.05	0	0	4	5	1	1	1	1	1	1	0	0	0	1.22	0.09	0.0002	0.4971	0.0536
171	5	0	2	2	1	0	8	2	60	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.64	0.11	0.0002	0.1756	0.0695
172	7	0	2	3	2	0	10	1	45	2	2	4	0	0	0.05	0	0	3	5	1	1	1	1	1	1	0	0	0	1.38	0.20	0.0002	0.7089	0.0764
173	7	1	4	1	1	0	12	1	45	1	1	4	0	0	0.05	0	0	3	4	1	0	1	0	0	1	0	0	0	1.38	0.13	0.0002	0.3030	0.0467
174	5	0	1	1	3	0	7	2	75	1	1	4	0	0	0.05	0	0	2	3	1	0	1	0	0	1	0	0	0	1.80	0.24	0.0002	0.4509	0.0864
175	7	2	1	1	3	0	10	2	60	0	1	2	0	0	0.05	0	0	2	3	1	0	1	0	0	1	0	0	0	1.56	0.09	0.0002	0.3037	0.0582
176	6	0	2	2	2	0	10	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.33	0.12	0.0002	0.0783	0.0620

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
177	6	0	1	1	4	0	7	2	75	0	0	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.56	0.03	0.0002	0.0000	0.0000
178	4	0	1	1	2	0	5	2	75	0	1	2	0	0	0.05	0	0	1	2	0	0	1	0	0	1	0	0	0	1.78	0.16	0.0002	0.2571	0.1018
179	4	0	3	1	0	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.12	0.0002	0.0947	0.0750
180	5	0	2	1	2	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.12	0.0002	0.0947	0.0750
181	4	0	2	1	1	0	7	2	60	1	1	4	0	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.89	0.24	0.0002	0.9418	0.1250
182	4	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.78	0.20	0.0002	0.0000	0.0000
183	7	1	1	1	4	0	10	2	0	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.33	0.10	0.0002	0.1565	0.0620
184	8	0	4	2	2	0	12	1	45	1	1	3	0	0	0.05	0	0	3	2	0	0	1	0	0	1	0	0	0	1.27	0.10	0.0002	0.1091	0.0432
185	2	2	0	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.92	0.20	0.0002	0.2250	0.1781
186	5	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.13	0.0002	0.0000	0.0000
187	6	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.05	0.0002	0.0947	0.0000
188	9	1	2	2	4	0	12	1	45	1	1	3	0	0	0.05	0	0	3	3	1	0	1	0	0	1	0	0	0	1.31	0.10	0.0002	0.2325	0.0445
189	6	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.08	0.0002	0.0947	0.0750
190	5	0	3	1	1	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.45	0.13	0.0002	0.0837	0.0663
191	2	2	0	0	0	0	5	1	0	1	1	4	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.92	0.49	0.0002	0.2250	0.1781
192	7	1	3	1	2	0	12	1	45	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.50	0.10	0.0002	0.4264	0.0737
193	10	1	3	2	4	0	15	2	0	0	1	2	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.15	0.06	0.0002	0.0486	0.0385
194	7	2	3	2	0	2	12	1	30	1	1	3	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.36	0.10	0.0002	0.3983	0.0598
195	7	0	2	3	2	0	10	1	45	1	2	2	0	0	0.05	0	0	3	4	1	1	1	1	1	1	0	0	0	1.38	0.14	0.0002	0.6422	0.0764
196	9	0	3	3	3	0	12	1	45	1	2	2	0	0	0.05	0	0	3	4	1	1	1	1	1	1	0	0	0	1.22	0.11	0.0002	0.5026	0.0598
197	6	0	3	2	1	0	10	2	0	1	1	3	0	0	0.05	0	0	3	2	0	0	1	0	0	1	0	0	0	1.20	0.13	0.0002	0.1412	0.0559
198	5	0	2	1	2	0	7	2	60	1	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.64	0.17	0.0002	0.7232	0.1086

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
199	4	0	1	1	2	0	5	2	75	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.78	0.16	0.0002	0.1286	0.1018
200	4	1	1	2	0	0	7	2	60	1	1	4	0	0	0.05	0	0	2	4	1	1	1	1	1	1	0	0	0	1.83	0.23	0.0002	1.0200	0.1213
201	4	0	2	2	0	1	7	2	60	0	1	2	0	0	0.05	0	0	2	3	0	0	1	0	0	1	0	0	0	1.58	0.11	0.0002	0.2734	0.0722
202	5	0	1	1	3	0	5	2	75	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.51	0.13	0.0002	0.2182	0.0864
203	6	1	1	1	3	0	7	2	60	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.52	0.11	0.0002	0.1756	0.0695
204	8	1	2	2	3	0	12	1	45	1	2	4	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.42	0.17	0.0002	0.1912	0.0483
205	8	0	2	2	4	0	12	2	60	1	2	4	0	0	0.05	0	0	3	3	1	1	1	1	1	1	0	0	0	1.53	0.17	0.0002	0.5550	0.0737
206	10	0	3	3	4	0	15	1	45	0	1	2	0	0	0.05	0	0	4	3	1	1	1	1	1	1	0	0	0	1.33	0.06	0.0002	0.4200	0.0557
207	8	1	3	2	2	0	12	1	45	1	1	4	0	0	0.05	0	0	3	6	1	1	1	1	1	1	0	0	0	1.31	0.12	0.0002	0.6544	0.0645
208	8	0	3	3	2	0	12	1	45	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.31	0.07	0.0002	0.0563	0.0445
209	8	2	1	2	3	0	12	1	45	1	1	3	0	0	0.05	0	0	3	5	1	1	1	1	1	1	0	0	0	1.47	0.12	0.0002	0.6716	0.0724
210	3	0	1	1	1	0	5	1	75	0	1	4	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.86	0.30	0.0002	0.0000	0.0000
211	5	1	1	1	2	0	7	2	60	0	1	1	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.73	0.09	0.0002	0.0000	0.0000
212	4	0	2	1	1	0	7	2	60	0	1	3	0	0	0.05	0	0	2	4	1	1	1	1	1	1	0	0	0	1.89	0.17	0.0002	1.0509	0.1250
213	6	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.05	0.0002	0.0000	0.0000
214	5	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.06	0.0002	0.1091	0.0864
215	6	0	2	2	2	0	10	2	0	0	1	3	0	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.33	0.12	0.0002	0.6757	0.0897
216	6	0	2	2	2	0	10	2	60	0	1	1	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.66	0.07	0.0002	0.5974	0.0897
217	7	0	3	2	2	0	12	1	45	1	1	3	0	0	0.05	0	0	3	4	1	1	1	1	1	1	0	0	0	1.50	0.12	0.0002	0.6193	0.0737
218	8	0	2	3	3	0	12	1	45	0	1	1	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.42	0.05	0.0002	0.0000	0.0000
219	8	1	1	3	3	0	12	1	45	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.47	0.08	0.0002	0.4189	0.0724
220	15	0	4	4	7	0	15	1	30	1	1	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.01	0.07	0.0002	0.2232	0.0386

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Panthadiya Village		Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
		>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
221	5	0	2	2	1	0	7	2	60	1	1	3	0	0	0.05	0	0	2	4	1	1	1	1	1	1	0	0	0	1.52	0.16	0.0002	0.8459	0.1006
222	5	0	2	1	2	0	7	2	60	1	1	3	0	0	0.05	0	0	2	4	1	1	1	1	1	1	0	0	0	1.64	0.17	0.0002	0.9126	0.1086
223	4	0	1	1	2	0	5	2	75	1	1	3	0	0	0.05	0	0	1	4	1	1	1	1	1	1	0	0	0	1.78	0.23	0.0002	1.2386	0.1473
224	7	1	1	1	4	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.33	0.07	0.0002	0.0783	0.0620
225	12	2	2	2	6	0	12	1	30	2	1	5	0	0	0.05	0	0	4	4	2	1	1	1	1	1	0	0	0	1.15	0.12	0.0002	0.4727	0.0503
226	4	1	2	1	0	1	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.70	0.11	0.0002	0.0911	0.0608
227	5	0	3	1	1	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.43	0.07	0.0002	0.0837	0.0105
228	4	0	1	1	2	0	5	2	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.20	0.0002	0.1286	0.1018
229	6	0	1	2	3	0	10	2	60	2	2	3	0	0	0.05	0	0	2	7	2	1	1	1	1	1	0	0	0	1.87	0.23	0.0002	1.2088	0.1006
230	6	2	1	1	2	0	8	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.18	0.13	0.0002	0.0818	0.0102
231	6	0	4	2	0	1	12	1	45	0	1	2	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.41	0.07	0.0002	0.4618	0.0693
232	8	0	2	3	3	0	12	1	45	1	2	4	0	0	0.05	0	0	3	5	1	0	1	0	0	1	0	0	0	1.42	0.17	0.0002	0.3742	0.0483
233	8	0	2	2	4	0	12	2	60	0	1	2	0	0	0.05	0	0	3	3	1	0	1	0	0	1	0	0	0	1.53	0.08	0.0002	0.2657	0.0509
234	8	1	1	1	5	0	10	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.20	0.06	0.0002	0.0706	0.0559
235	9	1	2	2	4	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.11	0.05	0.0002	0.0563	0.0445
236	8	1	4	2	1	0	15	1	30	1	1	4	0	0	0.05	0	0	3	4	1	1	1	1	1	1	0	0	0	1.57	0.11	0.0002	0.5026	0.0598
237	19	2	4	4	9	0	25	2	0	1	1	2	0	0	0.05	0	0	7	3	0	0	1	0	0	1	0	0	0	0.99	0.04	0.0002	0.0812	0.0214
238	6	0	5	1	0	0	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.22	0.08	0.0002	0.0621	0.0491
239	6	0	3	1	2	0	10	2	60	2	2	4	0	0	0.05	0	0	2	3	1	0	1	0	0	1	0	0	0	1.59	0.22	0.0002	0.3100	0.0594
240	15	2	3	3	7	0	15	1	30	3	2	5	0	0	0.05	0	0	5	8	2	1	1	1	1	1	0	0	0	1.03	0.12	0.0002	0.5063	0.0393
																													1.495	0.10	0.0002	0.212	0.055

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
1	2	0	0	0	0	3	1	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.39	0.08	0.0002	0.0000	0.0000
2	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
3	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.04	0.0002	0.1091	0.0727
4	0	1	1	1	2	5	1	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.11	0.0002	0.1200	0.0800
5	0	1	1	0	2	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.71	0.13	0.0002	0.1440	0.1140
6	0	2	2	1	1	10	2	60	1	1	2	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.72	0.12	0.0002	0.5366	0.0826
7	0	1	1	3	0	7	1	75	1	1	2	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.53	0.16	0.0002	0.7236	0.1114
8	0	1	1	1	1	5	1	75	1	1	2	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.67	0.20	0.0002	0.9011	0.1387
9	0	1	1	1	0	5	1	75	2	1	4	0	0	0.05	0	0	1	1	1	0	1	0	0	0	0	0	0	1.78	0.38	0.0002	0.3339	0.1043
10	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.74	0.10	0.0002	0.1091	0.0727
11	0	1	1	0	1	5	1	75	1	1	0	0	0	0.05	0	0	1	1	0	1	1	1	1	1	0	0	0	1.99	0.14	0.0002	0.9209	0.1919
12	0	3	3	0	1	12	2	0	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.19	0.08	0.0002	0.4153	0.0639
13	0	1	1	1	2	5	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.26	0.04	0.0002	0.1200	0.0800
14	2	1	1	0	2	8	2	60	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.66	0.05	0.0002	0.0878	0.0585
15	0	1	1	3	0	7	1	75	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.53	0.04	0.0002	0.1091	0.0727
16	0	1	1	0	2	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.51	0.08	0.0002	0.1440	0.0960
17	0	1	1	0	2	5	1	75	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.71	0.08	0.0002	0.1440	0.0960
18	0	1	1	3	0	7	1	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.16	0.10	0.0002	0.1091	0.0727
19	0	0	1	3	0	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.14	0.0002	0.1565	0.1043
20	0	1	1	1	0	5	1	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.24	0.0002	0.1565	0.1043
21	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
22	0	1	1	1	1	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.48	0.12	0.0002	0.1358	0.0906
23	0	1	1	4	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.17	0.0002	0.0947	0.0632

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
1	2	0	0	0	0	3	1	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.39	0.08	0.0002	0.0000	0.0000
2	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
3	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.04	0.0002	0.1091	0.0727
4	0	1	1	1	2	5	1	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.11	0.0002	0.1200	0.0800
5	0	1	1	0	2	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.71	0.13	0.0002	0.1440	0.1140
6	0	2	2	1	1	10	2	60	1	1	2	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.72	0.12	0.0002	0.5366	0.0826
7	0	1	1	3	0	7	1	75	1	1	2	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.53	0.16	0.0002	0.7236	0.1114
8	0	1	1	1	1	5	1	75	1	1	2	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.67	0.20	0.0002	0.9011	0.1387
9	0	1	1	1	0	5	1	75	2	1	4	0	0	0.05	0	0	1	1	1	0	1	0	0	0	0	0	0	1.78	0.38	0.0002	0.3339	0.1043
10	0	1	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.74	0.10	0.0002	0.1091	0.0727
11	0	1	1	0	1	5	1	75	1	1	0	0	0	0.05	0	0	1	1	0	1	1	1	1	1	0	0	0	1.99	0.14	0.0002	0.9209	0.1919
12	0	3	3	0	1	12	2	0	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.19	0.08	0.0002	0.4153	0.0639
13	0	1	1	1	2	5	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.26	0.04	0.0002	0.1200	0.0800
14	2	1	1	0	2	8	2	60	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.66	0.05	0.0002	0.0878	0.0585
15	0	1	1	3	0	7	1	75	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.53	0.04	0.0002	0.1091	0.0727
16	0	1	1	0	2	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.51	0.08	0.0002	0.1440	0.0960
17	0	1	1	0	2	5	1	75	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.71	0.08	0.0002	0.1440	0.0960
18	0	1	1	3	0	7	1	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.16	0.10	0.0002	0.1091	0.0727
19	0	0	1	3	0	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.14	0.0002	0.1565	0.1043
20	0	1	1	1	0	5	1	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.24	0.0002	0.1565	0.1043
21	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
22	0	1	1	1	1	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.48	0.12	0.0002	0.1358	0.0906
23	0	1	1	4	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.17	0.0002	0.0947	0.0632

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
24	0	1	1	2	2	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.35	0.09	0.0002	0.1029	0.0686
25	0	1	1	2	2	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.35	0.13	0.0002	0.1029	0.0686
26	0	1	1	3	0	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.17	0.0002	0.1091	0.0727
27	0	1	1	2	0	5	1	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.53	0.20	0.0002	0.1286	0.0857
28	0	3	3	2	2	15	1	45	1	1	4	0	0	0.05	0	0	4	2	1	1	1	1	1	0	0	0	0	1.38	0.11	0.0002	0.3870	0.0518
29	2	0	0	0	0	3	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.83	0.20	0.0002	0.2250	0.0000
30	0	3	3	1	4	15	1	45	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.32	0.08	0.0002	0.0493	0.0329
31	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.13	0.0002	0.1091	0.0727
32	0	1	1	1	0	5	1	75	0	1	3	0	0	0.05	0	0	1	2	1	1	1	1	1	0	0	0	0	1.78	0.24	0.0002	1.1948	0.1598
33	0	1	1	2	0	5	1	75	0	1	3	0	0	0.05	0	0	1	2	1	1	1	1	1	0	0	0	0	1.53	0.20	0.0002	0.9814	0.1313
34	2	0	0	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.92	0.13	0.0002	0.2250	0.0000
35	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
36	0	1	1	0	0	5	1	0	0	0	2	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.13	0.0002	0.0000	0.0000
37	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0000
38	0	1	1	1	1	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.48	0.12	0.0002	0.1358	0.0906
39	0	3	1	0	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.32	0.08	0.0002	0.0947	0.0632
40	0	2	2	1	1	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.38	0.10	0.0002	0.0809	0.0539
41	0	2	1	3	0	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.0837	0.0558
42	1	2	2	3	0	12	2	0	1	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.18	0.11	0.0002	0.0610	0.0407
43	0	1	1	3	0	7	2	0	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.20	0.0002	0.1091	0.0727
44	1	1	1	5	0	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.22	0.09	0.0002	0.0706	0.0471
45	0	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.69	0.11	0.0002	0.1286	0.0857
46	2	2	2	3	2	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.14	0.08	0.0002	0.0486	0.0324

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
47	2	2	2	0	2	12	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.18	0.09	0.0002	0.0610	0.0407
48	0	2	1	0	0	5	2	0	0	1	3	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.20	0.0002	0.1286	0.0000
49	0	2	2	1	1	10	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.72	0.10	0.0002	0.0809	0.0539
50	0	2	2	1	0	7	2	60	1	1	3	0	0	0.05	0	0	2	4	1	1	1	1	1	1	0	0	0	1.52	0.16	0.0002	0.8459	0.1006
51	0	3	3	0	4	15	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	0	0	0	0	0	0	0	1.25	0.08	0.0002	0.0529	0.0000
52	2	0	0	0	0	3	1	0	0	1	1	0	0	0.05	0	0	1	1	0	1	1	1	1	1	0	0	0	1.39	0.20	0.0002	1.2375	0.2578
53	0	1	1	2	0	5	1	75	2	2	3	0	0	0.05	0	0	1	4	1	1	1	1	1	1	0	0	0	1.53	0.34	0.0002	1.2386	0.1473
54	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.10	0.0002	0.1091	0.0727
55	0	1	1	1	1	5	1	75	0	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.67	0.21	0.0002	0.9011	0.1387
56	0	3	2	0	2	10	1	45	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.41	0.11	0.0002	0.0679	0.0453
57	0	3	2	0	2	10	1	45	0	1	1	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.41	0.06	0.0002	0.4506	0.0693
58	0	1	1	2	0	5	1	75	0	1	3	0	0	0.05	0	0	1	3	1	1	1	1	1	0	0	0	0	1.53	0.20	0.0002	1.1100	0.1313
59	1	1	1	3	0	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.66	0.11	0.0002	0.0878	0.0585
60	1	1	1	0	2	7	2	60	1	1	3	0	0	0.05	0	0	2	2	0	0	1	0	0	1	0	0	0	1.37	0.20	0.0002	0.2182	0.0864
61	2	1	1	0	2	7	2	60	1	1	5	1	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.52	0.24	0.0002	0.7580	0.1006
62	0	1	1	0	0	5	1	0	1	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.71	0.23	0.0002	1.3267	0.2292
63	0	1	1	1	3	7	1	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.52	0.10	0.0002	0.1075	0.0851
64	0	1	1	1	0	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.78	0.14	0.0002	0.1565	0.1239
65	0	1	1	1	0	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.78	0.14	0.0002	0.1565	0.1239
66	1	1	1	2	0	7	2	60	1	1	4	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.76	0.22	0.0002	0.6633	0.1146
67	0	3	1	0	0	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.72	0.12	0.0002	0.0947	0.0750
68	0	1	1	2	0	5	1	75	1	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.53	0.23	0.0002	0.1286	0.1018
69	0	1	1	4	0	7	2	75	1	1	5	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.56	0.24	0.0002	0.7232	0.1086

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
70	1	2	2	4	4	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.09	0.07	0.0002	0.0462	0.0365
71	0	4	3	0	2	15	2	0	0	1	3	1	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.20	0.09	0.0002	0.0507	0.0401
72	0	2	1	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.11	0.0002	0.1286	0.1018
73	0	2	1	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.11	0.0002	0.1286	0.1018
74	0	3	1	0	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.37	0.08	0.0002	0.0947	0.0750
75	1	3	3	4	0	15	1	30	1	1	3	0	0	0.05	0	0	4	3	1	1	1	1	1	1	0	0	0	1.32	0.08	0.0002	0.3790	0.0503
76	0	2	2	3	0	10	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.22	0.11	0.0002	0.0706	0.0559
77	0	5	5	1	8	25	2	0	1	1	3	0	0	0.05	0	0	6	1	0	0	1	0	0	1	0	0	0	1.06	0.05	0.0002	0.0293	0.0232
78	0	1	1	3	0	7	1	75	0	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.53	0.17	0.0002	0.8327	0.1250
79	0	1	1	0	2	5	1	75	0	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.71	0.13	0.0002	0.9552	0.1650
80	0	3	3	3	0	15	2	45	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.52	0.10	0.0002	0.3461	0.0598
81	0	1	1	2	0	5	1	75	1	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.53	0.23	0.0002	0.1286	0.1018
82	0	2	2	1	0	7	2	60	1	1	4	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.52	0.19	0.0002	0.5824	0.1006
83	2	2	2	0	0	10	1	45	1	1	3	0	0	0.05	0	0	3	4	1	1	1	1	1	1	0	0	0	1.47	0.13	0.0002	0.6669	0.0793
84	0	2	2	0	1	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.58	0.14	0.0002	0.6046	0.1044
85	0	2	2	0	2	10	2	60	1	1	5	0	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.78	0.21	0.0002	0.7228	0.0959
86	1	2	2	4	0	15	1	45	1	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.53	0.08	0.0002	0.0563	0.0445
87	2	1	1	3	0	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.23	0.09	0.0002	0.0735	0.0092
88	0	1	1	4	0	7	1	75	1	1	4	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.37	0.20	0.0002	0.6284	0.1086
89	0	1	1	1	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.56	0.14	0.0002	0.1565	0.1239
90	0	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.69	0.11	0.0002	0.1286	0.1018
91	0	1	1	0	1	5	2	0	0	0	1	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.76	0.06	0.0002	0.0000	0.0000
92	2	2	2	4	0	10	2	30	2	2	8	0	0	0.05	0	0	4	10	3	1	1	1	1	1	0	0	0	1.27	0.22	0.0002	0.8950	0.0573

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 1st Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
93	0	2	2	0	2	10	2	60	1	1	5	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.78	0.21	0.0002	0.1786	0.0663
94	2	3	3	2	0	15	2	0	1	1	4	0	0	0.05	0	0	4	3	1	1	1	1	1	1	0	0	0	1.06	0.10	0.0002	0.3885	0.0516
95	0	1	1	2	0	5	1	75	1	1	4	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.53	0.28	0.0002	0.8529	0.1473
96	0	2	2	0	1	7	2	60	2	2	4	0	0	0.05	0	0	2	5	2	1	1	1	1	1	0	0	0	1.58	0.27	0.0002	1.0724	0.1044
97	1	1	1	2	0	7	2	60	2	1	4	1	0	0.05	0	0	2	5	2	1	1	1	1	1	0	0	0	1.76	0.26	0.0002	1.1767	0.1146
98	1	1	1	3	0	8	2	60	1	1	5	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.66	0.22	0.0002	0.5824	0.1006
99	2	3	3	0	0	15	2	0	1	1	3	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.21	0.09	0.0002	0.3411	0.0589
100	2	1	1	2	0	10	2	60	1	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.74	0.15	0.0002	0.6245	0.0938
101	1	1	1	2	0	7	2	60	0	1	1	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.76	0.09	0.0002	0.6633	0.1146
																												1.499	0.14	0.0002	0.344	0.082

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
1	1	1	1	3	0	8	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.27	0.03	0.0002	0.0878	0.0585
2	0	1	1	2	0	5	2	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
3	2	0	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.92	0.20	0.0002	0.2250	0.0000
4	2	0	0	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.92	0.13	0.0002	0.2250	0.0000
5	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.04	0.0002	0.1091	0.0000
6	1	1	1	4	0	10	2	0	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.33	0.14	0.0002	0.0783	0.0522
7	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0727
8	0	1	1	3	0	7	2	0	1	0	3	0	0	0.05	0	0	2	1	1	0	1	0	0	0	0	0	0	1.43	0.14	0.0002	0.2327	0.0727
9	0	2	1	3	0	8	2	60	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.56	0.00	0.0002	0.0000	0.0000
10	2	0	0	0	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.92	0.00	0.0002	0.0000	0.0000
11	0	2	1	2	0	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.15	0.0002	0.0947	0.0632
12	0	1	1	3	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.04	0.0002	0.1091	0.0727
13	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.13	0.0002	0.1091	0.0727
14	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0727
15	0	1	1	0	2	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.51	0.13	0.0002	0.1440	0.0960
16	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	2	0	0	1	0	0	0	0	0	0	1.43	0.13	0.0002	0.2182	0.0727
17	0	2	2	0	0	7	2	0	1	2	2	0	0	0.05	0	0	2	2	0	0	1	0	0	0	0	0	0	1.31	0.20	0.0002	0.2000	0.0667
18	0	3	2	0	2	10	1	45	1	2	3	0	0	0.05	0	0	3	2	1	0	1	1	0	0	0	0	0	1.41	0.16	0.0002	0.2128	0.0566
19	2	2	0	0	0	7	2	0	1	2	2	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.31	0.20	0.0002	0.7633	0.1146
20	0	1	0	0	0	2	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.65	0.20	0.0002	0.3600	0.0000
21	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0857
22	0	1	1	2	0	5	2	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
23	1	1	0	0	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.00	0.0002	0.0000	0.0000

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
24	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.31	0.09	0.0002	0.1000	0.0667
25	0	1	0	0	0	2	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.65	0.00	0.0002	0.0000	0.0000
26	0	1	1	3	0	7	2	0	1	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.13	0.0002	0.1091	0.0727
27	0	1	1	0	1	5	1	75	1	0	2	0	0	0.05	0	0	1	2	1	1	1	1	1	0	0	0	0	1.99	0.16	0.0002	1.2781	0.1709
28	0	1	2	3	0	8	2	60	1	0	2	0	0	0.05	0	0	2	3	1	1	1	1	1	0	0	0	0	1.64	0.08	0.0002	0.7580	0.0896
29	0	3	3	4	0	15	2	0	1	1	3	0	0	0.05	0	0	4	2	1	0	1	0	0	0	0	0	0	1.15	0.09	0.0002	0.1524	0.0324
30	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	1	1	1	0	1	0	0	0	0	1.43	0.10	0.0002	0.7236	0.0932
31	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0857
32	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0727
33	0	1	1	2	0	5	2	75	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.04	0.0002	0.1286	0.0857
34	0	1	1	4	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.37	0.12	0.0002	0.0947	0.0000
35	0	2	1	3	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.21	0.07	0.0002	0.0837	0.0558
36	1	1	1	4	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.33	0.07	0.0002	0.0783	0.0522
37	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.13	0.0002	0.1091	0.0000
38	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.13	0.0002	0.1091	0.0000
39	0	1	1	2	0	5	2	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
40	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0000
41	1	1	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.71	0.18	0.0002	0.2000	0.0000
42	2	2	2	0	1	12	2	0	0	1	1	0	0	0.05	0	0	3	1	1	1	1	0	1	0	0	0	0	1.28	0.06	0.0002	0.4303	0.0554
43	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.04	0.0002	0.1286	0.0857
44	0	1	1	3	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
45	2	1	1	5	0	12	2	0	0	0	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.20	0.02	0.0002	0.0610	0.0407
46	0	1	0	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.53	0.00	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
47	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.04	0.0002	0.1286	0.0000
48	0	2	1	2	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.05	0.0002	0.0947	0.0000
49	0	3	2	1	0	10	2	0	0	0	0	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.20	0.00	0.0002	0.0000	0.0000
50	0	2	1	2	0	7	2	0	1	1	3	0	0	0.05	0	0	2	2	1	0	1	1	0	1	0	0	0	1.24	0.17	0.0002	0.2968	0.0908
51	0	2	2	0	0	7	2	0	1	1	3	0	0	0.05	0	0	2	2	1	0	1	1	0	0	0	0	0	1.31	0.18	0.0002	0.3133	0.0833
52	0	3	3	3	0	15	2	0	2	2	4	0	0	0.05	0	0	3	3	1	1	1	1	1	0	0	0	0	1.23	0.16	0.0002	0.4504	0.0533
53	1	0	0	0	0	3	1	0	0	1	2	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	2.66	0.55	0.0002	0.0000	0.0000
54	0	1	1	2	0	5	1	0	1	2	0	0	0	0.05	0	0	1	2	0	0	1	1	0	1	0	0	0	1.10	0.18	0.0002	0.2571	0.1232
55	0	1	1	2	1	5	2	0	1	1	3	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.20	0.21	0.0002	0.0000	0.0000
56	0	1	1	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.11	0.0002	0.0000	0.0000
57	0	1	0	0	0	2	1	0	0	1	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.65	0.20	0.0002	0.0000	0.0000
58	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.31	0.09	0.0002	0.1000	0.0792
59	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.11	0.0002	0.1286	0.1018
60	0	1	1	0	2	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.51	0.13	0.0002	0.1440	0.1140
61	0	3	3	2	2	15	2	45	1	1	3	0	0	0.05	0	0	4	3	1	1	1	1	1	1	0	0	0	1.48	0.09	0.0002	0.4377	0.0581
62	2	0	0	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.92	0.13	0.0002	0.2250	0.0281
63	0	2	1	2	0	7	2	60	1	1	0	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.64	0.08	0.0002	0.6284	0.1086
64	0	1	1	2	0	5	2	75	1	1	0	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.78	0.11	0.0002	0.8529	0.1473
65	0	1	1	3	0	7	2	0	1	1	0	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.43	0.09	0.0002	0.2327	0.0864
66	0	0	1	2	0	5	1	0	1	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.71	0.16	0.0002	0.2000	0.1583
67	0	1	1	0	0	5	1	75	1	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	2.38	0.23	0.0002	1.3267	0.2292
68	0	1	1	4	0	8	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.37	0.00	0.0002	0.0000	0.0000
69	1	1	1	3	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.08	0.0002	0.0878	0.0695

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
70	2	2	2	0	2	12	1	45	2	1	4	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.42	0.15	0.0002	0.4658	0.0699
71	0	1	1	3	0	7	2	75	1	0	1	0	0	0.05	0	0	2	2	1	0	1	1	0	1	0	0	0	1.80	0.07	0.0002	0.3418	0.1045
72	1	2	2	3	0	12	1	45	1	1	3	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.42	0.11	0.0002	0.4658	0.0699
73	0	1	1	4	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.12	0.0002	0.0947	0.0118
74	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	2	0	0	1	1	0	1	0	0	0	1.35	0.11	0.0002	0.2571	0.1232
75	1	1	1	3	1	8	2	0	1	1	1	0	0	0.05	0	0	2	2	0	0	1	1	0	1	0	0	0	1.17	0.09	0.0002	0.1618	0.0775
76	0	1	1	4	0	8	2	0	1	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.37	0.14	0.0002	0.0947	0.0118
77	0	1	1	0	0	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.71	0.24	0.0002	0.2000	0.0250
78	2	1	1	2	2	10	2	60	1	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.50	0.11	0.0002	0.0706	0.0559
79	2	2	2	0	0	10	2	0	1	0	3	0	0	0.05	0	0	3	2	1	0	1	1	0	1	0	0	0	1.18	0.09	0.0002	0.2169	0.0663
80	0	0	1	3	0	5	2	0	0	0	2	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.64	0.10	0.0002	0.1565	0.1239
81	0	0	1	1	0	3	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.63	0.00	0.0002	0.0000	0.0000
82	2	1	1	0	0	7	2	0	2	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.39	0.22	0.0002	0.8082	0.1213
83	0	2	1	0	0	7	1	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.43	0.20	0.0002	0.1286	0.1018
84	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.11	0.0002	0.1286	0.1018
85	0	1	1	4	0	7	2	0	0	0	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.03	0.0002	0.0947	0.0118
86	0	1	1	4	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.05	0.0002	0.0947	0.0118
87	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.80	0.20	0.0002	0.2327	0.0864
88	1	2	2	4	0	12	2	45	2	3	5	0	0	0.05	0	0	3	3	1	1	1	1	1	1	0	0	0	1.42	0.22	0.0002	0.4856	0.0645
89	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	2	1	0	0	1	0	1	0	0	0	1.31	0.09	0.0002	0.3133	0.0292
90	2	0	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	2	0	0	0	0	0	1	0	0	0	1.92	0.20	0.0002	0.4500	0.0281
91	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.78	0.11	0.0002	0.1286	0.1018
92	0	2	2	1	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	1	1	1	1	1	0	0	0	1.27	0.08	0.0002	0.4829	0.1006

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
93	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	2	1	1	1	1	1	1	0	0	0	1.35	0.11	0.0002	0.9814	0.1473
94	0	1	1	1	1	5	2	0	0	1	1	0	0	0.05	0	0	1	2	1	1	1	1	1	1	0	0	0	1.43	0.12	0.0002	1.0370	0.1557
95	0	2	2	0	1	8	2	60	0	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.70	0.14	0.0002	0.6957	0.1044
96	0	3	3	0	1	12	2	0	1	1	4	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.23	0.13	0.0002	0.1962	0.0496
97	1	1	1	3	0	8	2	60	1	1	3	0	0	0.05	0	0	2	2	1	0	1	0	0	1	0	0	0	1.64	0.16	0.0002	0.2751	0.0695
98	0	2	2	1	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.11	0.0002	0.0878	0.0695
99	0	1	1	6	0	10	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.28	0.12	0.0002	0.0750	0.0094
100	1	2	2	2	0	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	0	0	0	1	0	0	0	1.14	0.08	0.0002	0.0667	0.0083
101	0	1	1	3	0	7	2	75	1	0	1	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.80	0.07	0.0002	0.8327	0.1250
102	0	1	1	3	0	7	2	75	1	0	2	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.80	0.10	0.0002	0.8327	0.1250
103	0	1	1	0	1	5	1	75	1	1	2	0	0	0.05	0	0	1	2	1	1	1	1	1	1	0	0	0	1.99	0.25	0.0002	1.2781	0.1919
104	2	2	2	4	0	15	2	0	0	1	2	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.18	0.06	0.0002	0.0500	0.0396
105	2	2	2	0	0	10	2	0	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.18	0.08	0.0002	0.4592	0.0793
106	0	3	1	0	0	7	2	0	0	1	3	0	0	0.05	0	0	2	2	1	0	1	0	0	1	0	0	0	1.24	0.15	0.0002	0.2968	0.0750
107	2	1	1	2	0	8	2	60	2	1	2	2	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.52	0.18	0.0002	0.6245	0.0938
108	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0864
109	2	2	2	2	0	12	2	0	1	2	3	0	0	0.05	0	0	3	1	1	0	1	0	0	1	0	0	0	1.14	0.14	0.0002	0.1239	0.0460
110	1	1	1	3	0	8	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.64	0.08	0.0002	0.0878	0.0695
111	0	1	1	2	0	5	2	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
112	0	1	1	2	0	5	2	75	2	2	3	0	0	0.05	0	0	1	3	1	1	1	1	1	1	0	0	0	1.78	0.34	0.0002	1.1100	0.1473
113	0	1	1	2	0	5	2	75	2	2	3	0	0	0.05	0	0	1	3	1	1	1	1	1	1	0	0	0	1.78	0.34	0.0002	1.1100	0.1473
114	0	1	1	2	0	5	2	75	2	2	3	0	0	0.05	0	0	1	3	1	1	1	1	1	1	0	0	0	1.78	0.34	0.0002	1.1100	0.1473
115	2	1	1	3	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.25	0.07	0.0002	0.1567	0.0582

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Bisanpura 2nd Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
116	0	0	1	1	0	3	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.63	0.00	0.0002	0.0000	0.0000
117	1	1	2	4	0	10	2	60	0	1	3	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.42	0.10	0.0002	0.5089	0.0764
118	2	1	1	4	0	10	2	60	1	1	3	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.42	0.12	0.0002	0.2089	0.0528
119	0	3	3	0	0	10	2	45	1	1	2	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.51	0.10	0.0002	0.2089	0.0528
120	0	3	4	0	3	15	2	0	0	1	1	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.17	0.04	0.0002	0.0497	0.0393
121	0	1	1	2	2	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
122	1	1	1	3	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.27	0.11	0.0002	0.0878	0.0110
123	0	3	2	3	0	12	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.16	0.09	0.0002	0.0590	0.0467
124	2	4	4	4	1	20	2	30	2	2	4	0	0	0.05	0	0	6	2	1	1	1	1	1	1	0	0	0	1.25	0.10	0.0002	0.2465	0.0370
125	1	1	1	3	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.11	0.0002	0.0878	0.0695
126	1	2	2	6	0	15	2	45	2	2	4	0	0	0.05	0	0	4	3	1	0	1	1	0	1	0	0	0	1.42	0.14	0.0002	0.2011	0.0466
127	0	3	1	0	0	7	2	60	2	2	4	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.64	0.28	0.0002	0.7232	0.1086
128	2	2	2	4	0	15	2	30	0	1	3	0	0	0.05	0	0	4	2	1	1	1	1	1	1	0	0	0	1.60	0.08	0.0002	0.3817	0.0573
129	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	2	1	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.3418	0.0864
130	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	2	1	0	1	0	0	1	0	0	0	1.31	0.09	0.0002	0.3133	0.0792
131	1	1	1	3	0	8	2	0	0	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.27	0.14	0.0002	0.1873	0.0695
132	2	2	2	5	0	15	2	0	1	0	3	0	0	0.05	0	0	4	1	1	0	0	0	0	1	0	0	0	1.10	0.06	0.0002	0.0997	0.0058
133	0	1	1	2	0	5	2	0	0	0	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.04	0.0002	0.1286	0.1018
134	1	6	0	0	0	15	2	0	2	2	3	0	0	0.05	0	0	3	3	1	1	1	1	1	1	0	0	0	1.25	0.14	0.0002	0.4571	0.0607
135	0	2	1	1	0	7	2	60	2	2	3	0	0	0.05	0	0	2	3	1	1	1	1	1	1	0	0	0	1.89	0.29	0.0002	0.9418	0.1250
																												1.463	0.12	0.0002	0.274	0.061

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
1	0	0	1	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.00	0.0002	0.0000	0.0000
2	0	1	1	2	2	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.69	0.09	0.0002	0.1029	0.0686
3	0	2	1	1	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.89	0.13	0.0002	0.1091	0.0727
4	0	1	1	1	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.33	0.00	0.0002	0.0000	0.0000
5	1	1	1	4	1	10	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.00	0.0002	0.0000	0.0000
6	0	2	1	1	0	7	1	60	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.67	0.20	0.0002	0.7236	0.1114
7	1	2	2	0	0	8	1	45	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.48	0.13	0.0002	0.5427	0.0835
8	0	2	2	4	1	12	2	60	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.44	0.11	0.0002	0.4013	0.0618
9	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.80	0.20	0.0002	0.7236	0.1114
10	0	3	3	2	1	12	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.05	0.08	0.0002	0.0533	0.0356
11	0	2	1	3	0	8	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.21	0.13	0.0002	0.0837	0.0558
12	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.20	0.0002	0.1286	0.0857
13	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.20	0.0002	0.1286	0.0857
14	2	0	0	2	2	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
15	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	0	0	0	1	0	0	0	0	0	0	1.80	0.17	0.0002	0.0000	0.0727
16	0	1	1	3	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.13	0.0002	0.1091	0.0727
17	1	1	1	3	0	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.64	0.11	0.0002	0.0878	0.0585
18	0	1	1	6	0	10	2	75	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.53	0.00	0.0002	0.0000	0.0000
19	0	1	1	5	0	8	2	75	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.49	0.00	0.0002	0.0000	0.0000
20	0	1	1	4	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.00	0.0002	0.0000	0.0000
21	1	1	1	2	3	10	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.32	0.00	0.0002	0.0000	0.0000
22	0	1	1	2	0	5	1	75	0	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.53	0.20	0.0002	0.8529	0.1313
23	0	1	1	4	0	8	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.37	0.00	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
24	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.80	0.20	0.0002	0.7236	0.1114
25	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0857
26	1	1	0	0	0	4	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.44	0.00	0.0002	0.0000	0.0000
27	0	1	1	3	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.13	0.0002	0.1091	0.0727
28	0	1	1	0	2	5	1	75	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.71	0.13	0.0002	0.1440	0.0000
29	0	1	1	2	1	7	1	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.27	0.06	0.0002	0.1143	0.0000
30	1	3	3	0	1	12	2	30	1	2	4	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.54	0.15	0.0002	0.3646	0.0561
31	0	3	1	0	0	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.76	0.12	0.0002	0.0947	0.0632
32	0	3	1	1	0	8	2	60	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.07	0.0002	0.0837	0.0558
33	0	1	1	2	0	5	1	75	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.53	0.16	0.0002	0.1286	0.0857
34	1	2	2	0	3	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.13	0.08	0.0002	0.0661	0.0440
35	0	2	1	2	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.64	0.12	0.0002	0.0947	0.0632
36	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.17	0.0002	0.1091	0.0727
37	0	2	2	0	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.73	0.16	0.0002	0.6633	0.1021
38	0	3	1	2	0	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.28	0.09	0.0002	0.0750	0.0500
39	0	2	1	1	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	0	0	0	0	1.89	0.17	0.0002	0.2327	0.0727
40	0	1	1	4	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	0	0	0	0	1.56	0.15	0.0002	0.2021	0.0632
41	0	3	3	2	0	12	1	45	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.31	0.07	0.0002	0.0563	0.0375
42	2	2	2	2	0	12	1	30	1	2	4	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.52	0.16	0.0002	0.3852	0.0593
43	2	0	0	0	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.92	0.13	0.0002	0.2250	0.1500
44	0	1	1	3	0	8	1	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.73	0.17	0.0002	0.7236	0.1114
45	2	1	0	2	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.31	0.00	0.0002	0.0000	0.0000
46	0	2	1	2	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.00	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
47	0	1	1	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.10	0.00	0.0002	0.0000	0.0000
48	0	2	1	4	0	10	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.28	0.00	0.0002	0.0000	0.0000
49	2	1	1	0	2	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.27	0.08	0.0002	0.0878	0.0000
50	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0000
51	0	1	1	1	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.33	0.14	0.0002	0.1565	0.0000
52	0	1	1	0	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.00	0.0002	0.0000	0.0000
53	0	2	2	5	0	12	2	0	0	0	0	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.16	0.00	0.0002	0.0000	0.0000
54	1	1	1	1	0	7	1	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.78	0.18	0.0002	0.1161	0.0774
55	0	0	1	4	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.11	0.0002	0.1286	0.0857
56	0	1	1	4	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.08	0.0002	0.0947	0.0632
57	2	2	2	1	0	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.24	0.08	0.0002	0.0632	0.0421
58	2	2	2	0	3	12	1	45	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.34	0.10	0.0002	0.3821	0.0588
59	0	3	3	1	0	12	1	45	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.42	0.09	0.0002	0.4047	0.0623
60	1	3	3	5	1	15	2	0	0	1	3	0	0	0.05	0	0	5	1	0	0	1	0	0	0	0	0	0	0.94	0.06	0.0002	0.0398	0.0265
61	0	1	1	4	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.12	0.0002	0.0947	0.0632
62	0	0	1	3	0	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.33	0.19	0.0002	0.1565	0.1043
63	1	1	1	1	1	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.37	0.13	0.0002	0.1043	0.0696
64	2	2	2	0	2	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.20	0.07	0.0002	0.0610	0.0407
65	2	1	1	0	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.39	0.09	0.0002	0.1059	0.0706
66	0	3	3	0	1	12	1	45	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.46	0.10	0.0002	0.4153	0.0639
67	0	4	4	0	0	15	2	30	0	1	3	0	0	0.05	0	0	4	1	1	1	1	1	1	0	0	0	0	1.60	0.08	0.0002	0.3317	0.0510
68	1	2	1	1	0	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.64	0.14	0.0002	0.5824	0.0896
69	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.80	0.17	0.0002	0.7236	0.1114

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
70	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.78	0.20	0.0002	0.8529	0.1313
71	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.1091	0.0000
72	1	2	1	2	1	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.06	0.0002	0.0727	0.0485
73	2	0	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0		0	0	0	1.92	0.20	0.0002	0.2250	0.0000
74	0	2	1	1	0	7	2	60	0	2	3	0	0	0.05	0	0	2	0	0	0	1	0	0	0	0	0	0	1.89	0.23	0.0002	0.0000	0.0727
75	0	1	1	1	2	7	1	75	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.74	0.00	0.0002	0.0000	0.0000
76	0	1	1	3	0	7	1	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.58	0.13	0.0002	0.1091	0.0727
77	0	1	1	2	0	7	1	75	0	1	2	0	0	0.05	0	0	1	0	0	0	1	0	0	0	0	0	0	1.87	0.16	0.0002	0.0000	0.0857
78	0	1	1	0	1	5	1	75	0	1	2	0	0	0.05	0	0	1	0	0	0	1	0	0	0	0	0	0	1.99	0.20	0.0002	0.0000	0.1116
79	1	4	4	4	1	20	2	30	1	1	3	0	0	0.05	0	0	5	1	1	1	1	1	1	0	0	0	0	1.34	0.06	0.0002	0.2307	0.0355
80	0	1	1	1	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.64	0.14	0.0002	0.1565	0.0000
81	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.10	0.0002	0.1091	0.0000
82	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.1091	0.0000
83	1	1	1	2	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.31	0.12	0.0002	0.1000	0.0000
84	1	2	0	0	0	5	2	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
85	0	4	3	0	0	12	1	30	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.47	0.09	0.0002	0.3731	0.0574
86	0	1	1	2	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.10	0.11	0.0002	0.1286	0.0000
87	0	1	1	1	1	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.16	0.08	0.0002	0.1358	0.0000
88	0	2	2	2	0	10	2	60	1	1	5	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.66	0.19	0.0002	0.5191	0.0799
89	0	1	1	3	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.13	0.0002	0.1091	0.0727
90	0	1	1	4	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.56	0.15	0.0002	0.6284	0.0967
91	0	3	2	0	0	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.33	0.07	0.0002	0.0783	0.0522
92	0	2	2	0	0	7	2	60	1	2	4	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.73	0.27	0.0002	0.1000	0.0667

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
93	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0632
94	0	1	1	2	0	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.10	0.16	0.0002	0.1286	0.0857
95	0	2	2	2	1	10	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.55	0.11	0.0002	0.0727	0.0485
96	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.78	0.20	0.0002	0.1286	0.0857
97	1	1	1	2	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.73	0.12	0.0002	0.1000	0.0667
98	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.1091	0.0000
99	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0000
100	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.31	0.09	0.0002	0.1000	0.0000
101	0	3	3	0	1	12	1	45	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.46	0.11	0.0002	0.4153	0.0639
102	0	2	1	1	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.89	0.17	0.0002	0.1091	0.0727
103	0	2	1	0	1	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.50	0.14	0.0002	0.1143	0.0762
104	0	2	1	0	0	5	2	60	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.89	0.20	0.0002	0.1286	0.0857
105	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0000
106	2	2	2	2	2	12	2	30	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.46	0.06	0.0002	0.0522	0.0348
107	2	2	2	2	2	12	2	30	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	0	0	0	0	1.46	0.06	0.0002	0.3461	0.0533
108	0	2	1	1	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
109	0	4	3	0	4	15	2	30	0	1	4	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.48	0.09	0.0002	0.0462	0.0308
110	1	4	3	2	0	15	2	30	1	1	4	0	0	0.05	0	0	4	1	1	1	1	1	1	0	0	0	0	1.41	0.09	0.0002	0.2912	0.0448
111	0	2	2	0	0	7	2	60	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.73	0.18	0.0002	0.6633	0.1021
112	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	1	1	1	1	0	0	0	0	1.80	0.17	0.0002	0.6000	0.1114
113	0	1	1	0	0	5	0	75	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.98	0.00	0.0002	0.0000	0.0000
114	1	2	2	2	0	10	1	45	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.38	0.10	0.0002	0.0667	0.0444
115	0	2	1	1	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.89	0.13	0.0002	0.1091	0.0727

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
116	0	1	1	3	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
117	0	1	1	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.10	0.00	0.0002	0.0000	0.0000
118	0	0	1	3	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.64	0.14	0.0002	0.1565	0.0000
119	2	1	1	2	0	8	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.52	0.10	0.0002	0.0818	0.0545
120	0	4	4	4	1	20	2	0	1	1	3	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.14	0.07	0.0002	0.2501	0.0432
121	0	2	2	4	1	12	2	60	1	2	2	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.44	0.12	0.0002	0.4013	0.0693
122	1	2	2	2	0	10	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.14	0.10	0.0002	0.0667	0.0444
123	0	1	1	2	0	5	1	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.10	0.20	0.0002	0.1286	0.0857
124	2	1	0	0	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.45	0.12	0.0002	0.1385	0.0000
125	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0857
126	0	1	1	4	0	8	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.69	0.08	0.0002	0.0947	0.0632
127	0	3	3	1	2	12	2	0	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.07	0.10	0.0002	0.3618	0.0625
128	0	3	3	0	0	10	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.14	0.06	0.0002	0.0667	0.0444
129	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.1091	0.0000
130	0	1	1	3	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.43	0.06	0.0002	0.1091	0.0000
131	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.31	0.09	0.0002	0.1000	0.0667
132	0	1	1	2	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.07	0.0002	0.1286	0.0000
133	0	2	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0000
134	2	1	1	3	0	10	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.56	0.11	0.0002	0.0735	0.0490
135	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.80	0.17	0.0002	0.1091	0.0727
136	0	1	1	1	0	5	1	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	0	0	0	0	1.86	0.24	0.0002	0.1565	0.1043
137	0	2	1	2	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	0	0	0	0	1.64	0.15	0.0002	0.6284	0.0967
138	2	2	2	0	1	12	1	45	0	0	0	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.51	0.00	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
139	0	0	1	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.00	0.0002	0.0000	0.0000
140	0	2	2	2	0	10	2	60	2	2	4	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.66	0.23	0.0002	0.5191	0.0897
141	0	1	1	2	0	5	1	75	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.53	0.00	0.0002	0.0000	0.0000
142	1	2	2	0	3	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	0	0	0	1	0	0	0	1.13	0.08	0.0002	0.0661	0.0083
143	0	1	1	0	2	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.23	0.00	0.0002	0.0000	0.0000
144	0	1	1	2	0	5	1	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.10	0.20	0.0002	0.1286	0.1018
145	1	1	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.31	0.09	0.0002	0.1000	0.0792
146	1	3	3	1	5	15	2	30	1	1	3	0	0	0.05	0	0	4	1	1	0	1	0	0	1	0	0	0	1.36	0.08	0.0002	0.0909	0.0337
147	2	1	1	0	2	8	2	60	1	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.64	0.16	0.0002	0.1873	0.0695
148	0	1	1	1	0	5	1	75	1	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.86	0.29	0.0002	1.0383	0.1793
149	1	3	3	1	1	15	1	30	1	2	5	0	0	0.05	0	0	4	2	1	1	0	1	1	1	0	0	0	1.53	0.16	0.0002	0.3898	0.0245
150	2	2	1	0	3	10	2	0	0	1	2	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.13	0.08	0.0002	0.4382	0.0757
151	0	1	1	2	0	5	2	75	0	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.78	0.11	0.0002	0.8529	0.1473
152	0	1	1	5	0	8	2	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.49	0.13	0.0002	0.5553	0.0959
153	0	1	1	2	1	7	2	75	0	1	1	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.88	0.10	0.0002	0.7581	0.1310
154	2	0	0	0	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.92	0.20	0.0002	1.4925	0.2578
155	0	1	1	4	0	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.37	0.08	0.0002	0.0947	0.0750
156	0	1	1	3	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.10	0.0002	0.1091	0.0864
157	0	1	1	2	0	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.10	0.11	0.0002	0.1286	0.0161
158	0	1	1	1	2	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.57	0.11	0.0002	0.1200	0.0950
159	0	1	1	2	0	5	1	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.10	0.20	0.0002	0.1286	0.1018
160	0	1	1	2	0	5	1	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.10	0.20	0.0002	0.1286	0.1018
161	1	1	1	2	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.31	0.12	0.0002	0.1000	0.0792

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
162	0	1	1	0	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.71	0.00	0.0002	0.0000	0.0000
163	0	1	1	0	3	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.08	0.15	0.0002	0.1263	0.1000
164	0	1	1	0	2	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.23	0.18	0.0002	0.1440	0.1140
165	0	1	1	1	1	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.43	0.12	0.0002	0.1358	0.1075
166	0	1	1	3	0	7	2	75	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.80	0.13	0.0002	0.1091	0.0864
167	1	1	1	3	0	8	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.11	0.0002	0.0878	0.0695
168	0	0	1	3	0	5	2	0	0	1	0	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.64	0.09	0.0002	0.1565	0.1239
169	2	2	2	0	2	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	0	0	0	1	0	0	0	1.20	0.07	0.0002	0.0610	0.0076
170	0	1	1	2	0	5	2	0	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.35	0.16	0.0002	0.1286	0.0161
171	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.80	0.17	0.0002	0.7236	0.1250
172	0	1	1	2	0	8	2	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.86	0.20	0.0002	0.1286	0.1018
173	0	1	1	3	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
174	0	2	2	0	3	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.32	0.07	0.0002	0.0774	0.0000
175	0	1	1	1	0	5	2	0	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.64	0.19	0.0002	0.1565	0.0000
176	0	2	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0000
177	0	1	1	1	2	5	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.26	0.07	0.0002	0.1200	0.0000
178	1	1	1	2	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.31	0.06	0.0002	0.1000	0.0000
179	0	3	2	1	1	10	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.13	0.08	0.0002	0.0661	0.0440
180	0	3	3	0	2	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.16	0.07	0.0002	0.0590	0.0393
181	0	1	1	2	1	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.50	0.10	0.0002	0.1143	0.0000
182	0	1	1	2	0	5	2	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	0	0	0	0	1.35	0.11	0.0002	0.1286	0.0000
183	0	3	3	0	4	15	2	45	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.55	0.10	0.0002	0.3512	0.0607
184	0	3	3	0	1	12	2	45	1	1	3	0	0	0.05	0	0	3	1	1	0	1	1	1	1	0	0	0	1.58	0.11	0.0002	0.1336	0.0717

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
185	0	3	1	0	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.64	0.12	0.0002	0.0947	0.0750
186	1	0	1	3	0	7	2	75	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.91	0.10	0.0002	0.1161	0.0919
187	1	1	1	0	2	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.89	0.17	0.0002	0.7236	0.1250
188	0	3	1	0	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.00	0.0002	0.0000	0.0000
189	0	1	2	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.31	0.09	0.0002	0.1000	0.0125
190	1	1	1	2	1	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.58	0.14	0.0002	0.6046	0.1044
191	2	2	1	2	2	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	0	0	0	1	0	0	0	1.16	0.05	0.0002	0.0590	0.0074
192	2	1	1	0	1	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.26	0.12	0.0002	0.0960	0.0640
193	0	3	3	0	0	10	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.14	0.10	0.0002	0.0667	0.0444
194	0	1	1	3	0	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.43	0.17	0.0002	0.1091	0.0727
195	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.24	0.08	0.0002	0.0947	0.0000
196	2	3	2	2	3	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	0	0	0	0	1.03	0.07	0.0002	0.0436	0.0291
197	0	3	3	1	1	12	2	45	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	0	0	0	0	1.46	0.07	0.0002	0.0576	0.0384
198	0	1	1	6	0	10	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.28	0.00	0.0002	0.0000	0.0000
199	1	1	1	1	0	7	2	0	0	1	0	0	0	0.05	0	0	2	1	0	0	0	0	0	0	0	0	0	1.52	0.06	0.0002	0.1161	0.0000
200	2	1	1	4	0	10	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	0	0	0	0	0	0	0	1.14	0.06	0.0002	0.0667	0.0000
201	1	0	1	0	0	5	0	75	0	1	2	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	2.23	0.28	0.0002	0.2250	0.1781
202	0	2	2	0	2	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.56	0.13	0.0002	0.5553	0.0959
203	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.80	0.20	0.0002	0.7236	0.1250
204	1	1	1	3	0	8	2	60	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.64	0.16	0.0002	0.5824	0.1006
205	0	1	1	0	0	5	1	0	0	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.71	0.31	0.0002	1.3267	0.2292
206	0	1	1	1	0	5	1	75	1	2	4	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.86	0.42	0.0002	1.0383	0.1793
207	0	1	1	2	0	5	1	75	1	2	4	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.53	0.35	0.0002	0.8529	0.1473

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
208	2	1	1	0	3	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.51	0.13	0.0002	0.5366	0.0927
209	0	1	1	4	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.15	0.0002	0.0947	0.0750
210	0	3	2	0	1	10	1	45	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.50	0.13	0.0002	0.4824	0.0833
211	2	1	1	2	0	8	2	60	1	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.52	0.12	0.0002	0.0818	0.0648
212	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.80	0.17	0.0002	0.1091	0.0864
213	1	1	1	3	0	8	2	0	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.27	0.16	0.0002	0.0878	0.0695
214	0	1	1	3	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.43	0.00	0.0002	0.0000	0.0000
215	1	1	2	3	0	10	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.11	0.0002	0.0735	0.0582
216	1	1	1	2	2	8	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.21	0.07	0.0002	0.0837	0.0105
217	2	1	1	2	1	10	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.29	0.09	0.0002	0.0758	0.0095
218	0	1	1	2	1	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.50	0.10	0.0002	0.1143	0.0143
219	0	2	1	2	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.08	0.0002	0.0947	0.0118
220	0	1	1	0	1	5	1	0	0	1	1	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.43	0.15	0.0002	0.1674	0.0209
221	0	3	3	2	2	15	2	0	0	1	1	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.20	0.05	0.0002	0.0507	0.0401
222	0	4	3	0	3	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.14	0.08	0.0002	0.0483	0.0383
223	2	2	2	0	0	10	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.18	0.11	0.0002	0.0692	0.0548
224	2	2	2	2	0	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.14	0.07	0.0002	0.0581	0.0460
225	1	3	3	2	3	15	2	30	0	1	4	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.40	0.08	0.0002	0.0436	0.0345
226	0	4	4	2	5	15	2	30	2	2	4	2	0	0.05	0	0	5	3	1	1	1	1	1	1	0	0	0	1.16	0.12	0.0002	0.3124	0.0415
227	0	3	3	0	4	15	2	0	1	1	3	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.25	0.10	0.0002	0.1659	0.0419
228	0	3	3	0	2	12	1	45	1	2	4	0	0	0.05	0	0	3	2	1	0	1	0	0	1	0	0	0	1.38	0.16	0.0002	0.1849	0.0467
229	0	1	1	1	0	5	1	75	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.86	0.19	0.0002	0.1565	0.0196
230	1	1	1	3	0	8	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.27	0.00	0.0002	0.0000	0.0000

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
231	0	3	3	0	1	12	1	45	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.46	0.10	0.0002	0.4153	0.0717
232	2	2	2	1	0	12	1	45	2	2	3	0	0	0.05	0	0	3	1	1	0	1	0	0	1	0	0	0	1.47	0.17	0.0002	0.1347	0.0500
233	0	1	1	3	0	7	2	75	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.80	0.00	0.0002	0.0000	0.0000
234	1	1	1	2	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.31	0.00	0.0002	0.0000	0.0000
235	1	3	4	3	2	15	2	30	1	1	3	0	0	0.05	0	0	5	1	1	0	1	1	0	1	0	0	0	1.25	0.07	0.0002	0.0835	0.0375
236	0	2	2	0	0	7	2	60	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.73	0.18	0.0002	0.6633	0.1146
237	2	4	3	5	0	20	2	30	1	1	4	0	0	0.05	0	0	5	1	1	0	1	0	0	1	0	0	0	1.32	0.07	0.0002	0.0731	0.0271
238	0	2	1	2	0	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.15	0.0002	0.0947	0.0750
239	0	2	1	0	0	5	2	0	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.35	0.20	0.0002	0.1286	0.1018
240	0	1	1	2	0	5	2	0	0	1	3	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.35	0.20	0.0002	0.1286	0.0161
241	2	2	1	0	0	8	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.18	0.13	0.0002	0.0818	0.0648
242	2	1	1	0	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.39	0.00	0.0002	0.0000	0.0000
243	0	3	1	1	0	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.56	0.13	0.0002	0.5553	0.0959
244	0	1	1	2	0	5	2	0	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.35	0.16	0.0002	0.1286	0.0161
245	0	2	1	0	0	5	2	0	0	1	2	0	0	0.05	0	0	1	1	1	1	1	1	1	0	0	0	0	1.35	0.16	0.0002	0.8529	0.1313
246	0	1	1	2	1	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.50	0.10	0.0002	0.1143	0.0143
247	0	1	1	2	0	5	1	0	0	1	0	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.10	0.07	0.0002	0.1286	0.0161
248	0	3	3	1	4	12	2	45	0	1	2	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.25	0.06	0.0002	0.3271	0.0565
249	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0864
250	1	1	1	2	0	7	2	0	1	2	4	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.31	0.27	0.0002	0.2133	0.0792
251	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.08	0.0002	0.0947	0.0750
252	2	1	1	3	1	10	2	60	1	1	5	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.46	0.17	0.0002	0.4549	0.0786
253	0	1	1	4	0	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.15	0.0002	0.0947	0.0750

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
254	1	3	3	3	0	15	2	0	1	1	4	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.10	0.10	0.0002	0.0468	0.0370
255	2	0	0	0	0	5	0	75	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	2.23	0.00	0.0002	0.0000	0.0000
256	0	4	4	2	0	15	1	30	1	1	3	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.32	0.08	0.0002	0.2912	0.0503
257	0	3	3	4	0	15	1	45	1	1	2	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.33	0.07	0.0002	0.3227	0.0557
258	1	2	1	0	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.31	0.00	0.0002	0.0000	0.0000
259	1	1	1	2	0	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.73	0.12	0.0002	0.1000	0.0125
260	1	0	0	0	0	3	1	0	0	0	0	0	0	0.05		0	0	0	0	0	0	0	0	0	0	0	0	2.66	0.00	0.0002	0.0000	0.0000
261	0	1	1	4	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.24	0.00	0.0002	0.0000	0.0000
262	1	1	1	2	0	7	2	0	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.31	0.00	0.0002	0.0000	0.0000
263	1	2	1	4	0	12	2	0	0	0	0	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.26	0.00	0.0002	0.0000	0.0000
264	1	2	2	0	2	10	2	0	0	0	0		0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.20	0.00	0.0002	0.0000	0.0000
265	2	1	1	0	2	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.64	0.14	0.0002	0.5824	0.1006
266	1	1	1	3	0	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.64	0.14	0.0002	0.1873	0.0695
267	0	3	3	0	1	12	2	0	1	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.23	0.11	0.0002	0.4153	0.0717
268	1	1	1	3	0	8	2	0	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.27	0.16	0.0002	0.5824	0.1006
269	1	1	1	2	0	7	2	0	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.31	0.18	0.0002	0.6633	0.1146
270	2	1	1	2	1	10	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.61	0.09	0.0002	0.0758	0.0600
271	0	3	3	0	1	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.23	0.08	0.0002	0.0626	0.0496
272	1	1	1	1	2	7	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.64	0.12	0.0002	0.0947	0.0750
273	2	2	3	1	1	12	2	30	2	2	6	0	0	0.05	0	0	3	2	1	1	1	1	1	1	0	0	0	1.48	0.19	0.0002	0.4012	0.0602
274	2	3	2	1	1	12	2	30	0	1	3	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.43	0.08	0.0002	0.3387	0.0585
275	0	2	2	0	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.73	0.16	0.0002	0.6633	0.1146
276	0	3	2	0	0	10	1	45	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.62	0.14	0.0002	0.5191	0.0897

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
277	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.80	0.20	0.0002	0.7236	0.1250
278	1	1	1	1	1	7	2	60	0	1	0	0	0	0.05	0	0	2	1	0	0	1	0	0	0	0	0	0	1.81	0.06	0.0002	0.1043	0.0696
279	0	2	1	1	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0864
280	0	1	1	0	1	5	1	75	1	1	3	0	0	0.05	0	0	1	1	1	1	0	0	1	1	0	0	0	1.99	0.31	0.0002	1.1107	0.0523
281	0	1	1	4	0	7	2	75	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.56	0.00	0.0002	0.0000	0.0000
282	0	1	1	2	0	5	2	75	1	1	3	0	0	0.05	0	0	1	1	1	0	0	0	0	1	0	0	0	1.78	0.23	0.0002	0.2743	0.0161
283	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	1	0	0	0	0	1	0	0	0	1.80	0.20	0.0002	0.2327	0.0136
284	1	0	1	2	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.18	0.00	0.0002	0.0000	0.0000
285	2	3	3	2	0	15	2	30	2	2	4	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.44	0.13	0.0002	0.2985	0.0516
286	2	2	2	5	0	15	2	45	2	2	4	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.37	0.14	0.0002	0.3101	0.0536
287	2	2	2	3	2	15	2	45	0	0	0	0	0	0.05	0	0	4	0	0	0	0	0	0	0	0	0	0	1.42	0.00	0.0002	0.0000	0.0000
288	2	3	3	2	0	15	1	30	0	0	0	0	0	0.05	0	0	4	0	0	0	0	0	0	0	0	0	0	1.35	0.00	0.0002	0.0000	0.0000
289	2	1	1	0	2	8	2	0	1	1	3	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.27	0.16	0.0002	0.0878	0.0110
290	1	3	3	2	0	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.18	0.08	0.0002	0.0500	0.0396
291	0	5	5	0	4	20	5	30	2	2	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.54	0.10	0.0002	0.2296	0.0397
292	0	1	1	4	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.15	0.0002	0.0947	0.0750
293	2	4	3	5	2	20	2	0	1	1	4	0	0	0.05	0	0	6	1	1	1	1	1	1	1	0	0	0	0.97	0.07	0.0002	0.2132	0.0368
294	0	5	5	1	5	20	2	30	1	1	4	0	0	0.05	0	0	6	1	1	1	1	1	1	1	0	0	0	1.23	0.07	0.0002	0.2123	0.0367
295	0	4	3	0	2	12	2	0	0	0	0	0	0	0.05	0	0	4	0	0	0	0	0	0	0	0	0	0	1.00	0.00	0.0002	0.0000	0.0000
296	1	2	1	1	1	8	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.51	0.13	0.0002	0.0809	0.0640
297	0	2	2	2	1	10	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.24	0.11	0.0002	0.0727	0.0576
298	1	1	1	2	0	8	2	60	1	1	4	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.86	0.22	0.0002	0.6633	0.1146
299	1	3	3	2	3	15	2	0	0	1	1	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.03	0.04	0.0002	0.0436	0.0345

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
300	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0864
301	1	1	1	0	0	5	1	60	0	1	3	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.76	0.22	0.0002	0.9185	0.1587
302	2	0	0	0	0	5	1	0	0	0	0	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0	0	1.92	0.00	0.0002	0.0000	0.0000
303	1	2	1	0	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.31	0.09	0.0002	0.1000	0.0125
304	1	4	1	0	0	12	2	0	0	1	3	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.26	0.10	0.0002	0.0643	0.0509
305	1	1	1	3	0	8	2	60	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.64	0.14	0.0002	0.5824	0.1006
306	0	3	3	3	6	15	2	0	0	1	2	0	0	0.05	0	0	5	1	0	0	1	0	0	1	0	0	0	0.94	0.05	0.0002	0.0400	0.0317
307	0	2	2	0	2	8	2	60	0	2	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.56	0.15	0.0002	0.0837	0.0663
308	1	2	2	2	5	12	2	0	0	2	2	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	0.99	0.09	0.0002	0.0503	0.0399
309	0	1	1	3	0	7	2	75	1	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.80	0.20	0.0002	0.1091	0.0864
310	1	0	0	0	0	3	0	0	0	0	0	0	0	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	1.77	0.00	0.0002	0.0000	0.0000
311	0	2	3	1	3	12	1	45	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.41	0.09	0.0002	0.4013	0.0693
312	1	3	2	3	1	15	2	0	1	2	4	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.17	0.13	0.0002	0.3294	0.0569
313	0	6	4	2	3	20	2	30	2	2	6	0	0	0.05	0	0	6	2	1	1	1	1	1	1	0	0	0	1.23	0.12	0.0002	0.2443	0.0367
314	1	3	3	1	0	12	2	0	0	1	1	0	0	0.05	0	0	3	1	0	0	0	0	0	1	0	0	0	1.06	0.05	0.0002	0.0537	0.0067
315	0	3	3	0	1	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.23	0.08	0.0002	0.0626	0.0496
316	1	4	3	0	0	15	2	0	0	1	3	0	0	0.05	0	0	4	1	0	0	1	0	0	1	0	0	0	1.18	0.08	0.0002	0.0500	0.0396
317	0	3	3	2	1	12	2	0	0	1	2	0	0	0.05	0	0	3	1	0	0	1	0	0	1	0	0	0	1.05	0.07	0.0002	0.0533	0.0422
318	0	1	1	2	0	5	1	75	1	2	4	0	0	0.05	0	0	1	1	1	1	1	1	1	1	0	0	0	1.53	0.35	0.0002	0.8529	0.1473
319	0	1	1	3	0	7	2	75	0	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.80	0.17	0.0002	0.7236	0.1250
320	2	1	1	1	1	8	2	60	1	1	4	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.58	0.18	0.0002	0.0847	0.0671
321	0	2	1	4	0	10	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.59	0.09	0.0002	0.0750	0.0594
322	0	1	1	3	0	7	2	0	0	1	2	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.43	0.13	0.0002	0.1091	0.0136

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
323	0	2	1	2	0	7	2	60	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.64	0.15	0.0002	0.0947	0.0750
324	1	1	1	2	1	7	2	0	0	1	3	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.20	0.14	0.0002	0.0911	0.0722
325	0	5	5	0	2	20	2	30	1	1	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.43	0.08	0.0002	0.2462	0.0425
326	1	1	1	4	0	10	2	60	0	1	2	0	0	0.05	0	0	2	1	0	0	1	0	0	1	0	0	0	1.66	0.10	0.0002	0.0783	0.0620
327	0	1	1	2	0	5	2	75	0	1	3	0	0	0.05	0	0	1	1	0	0	1	0	0	1	0	0	0	1.78	0.20	0.0002	0.1286	0.1018
328	2	2	2	3	0	12	2	45	1	1	3	0	0	0.05	0	0	3	1	1	0	1	0	0	1	0	0	0	1.36	0.10	0.0002	0.1146	0.0425
329	2	3	3	3	2	15	2	30	1	1	3	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.25	0.07	0.0002	0.2596	0.0448
330	0	1	1	2	0	5	1	0	0	1	2	0	0	0.05	0	0	1	1	0	0	0	0	0	1	0	0	0	1.10	0.16	0.0002	0.1286	0.0161
331	2	2	1	5	0	12	2	45	1	2	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.32	0.12	0.0002	0.3461	0.0598
332	0	3	4	6	1	15	2	30	1	1	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.21	0.08	0.0002	0.2501	0.0432
333	0	5	4	2	3	20	2	30	1	1	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.35	0.08	0.0002	0.2330	0.0402
334	1	3	3	6	1	15	2	30	1	3	0	0	0	0.05	0	0	5	3	1	0	1	1	0	1	0	0	0	1.21	0.07	0.0002	0.1558	0.0361
335	1	2	2	2	2	12	1	45	0	0	0	0	0	0.05	0	0	3	0	0	0	0	0	0	0	0	0	0	1.38	0.00	0.0002	0.0000	0.0000
336	0	2	1	4	0	10	2	60	0	0	0	0	0	0.05	0	0	2	0	0	0	0	0	0	0	0	0	0	1.59	0.00	0.0002	0.0000	0.0000
337	1	1	1	4	1	10	2	60	0	1	3	0	0	0.05	0	0	2	1	1	0	1	0	0	1	0	0	0	1.55	0.11	0.0002	0.1552	0.0576
338	0	1	1	4	0	7	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.08	0.0002	0.0947	0.0118
339	0	2	2	2	1	10	2	0	0	1	1	0	0	0.05	0	0	2	1	0	0	0	0	0	1	0	0	0	1.24	0.06	0.0002	0.0727	0.0091
340	2	2	1	2	0	10	1	45	1	2	5	0	0	0.05	0	0	3	1	1	0	0	0	0	1	0	0	0	1.38	0.20	0.0002	0.1422	0.0083
341	0	1	1	3	0	7	2	75	1	2	5	0	0	0.05	0	0	2	1	1	0	0	0	0	1	0	0	0	1.80	0.33	0.0002	0.2327	0.0136
342	2	3	1	2	0	12	2	60	0	1	3	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.34	0.09	0.0002	0.3731	0.0645
343	0	6	4	8	0	25	2	30	2	2	6	0	0	0.05	0	0	7	3	2	1	1	1	1	1	0	0	0	1.23	0.10	0.0002	0.2664	0.0313
344	1	4	4	5	3	20	2	0	1	1	3	0	0	0.05	0	0	6	1	1	0	1	0	0	1	0	0	0	0.94	0.06	0.0002	0.0665	0.0247
345	1	3	3	10	0	20	2	30	0	1	3	0	0	0.05	0	0	6	1	1	1	1	1	1	1	0	0	0	1.24	0.05	0.0002	0.2132	0.0368

Appendix-II

Estimated per Capita End-use Energy Requirements of the Surveyed Villages

Morva Village	Seniors	Men	Women	B&G	Kids	Cooking			Lighting						Heating			Cooling			Appliances							Total Cooking	Total Lighting	Total Heating	Total Cooling	Total Appliances
	>59	18to59	18to59	5to18	1to5	Bio	Dung	LPG	T	B100	B60	B40	B15	Kero	G	AH	Bio	F	C	R	T	MS	M	CC	WM	C	O	kWh/P	kWh/P	kWh/P	kWh/P	kWh/P
346	1	3	3	5	1	15	2	30	1	2	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.27	0.11	0.0002	0.2639	0.0456
347	2	1	1	0	0	7	2	60	1	1	3	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.83	0.19	0.0002	0.7024	0.1213
348	2	4	3	6	2	20	2	30	1	1	3	0	0	0.05	0	0	6	1	1	0	1	0	0	1	0	0	0	1.19	0.06	0.0002	0.0656	0.0244
349	0	3	3	0	1	12	1	45	1	2	4	0	0	0.05	0	0	3	1	1	1	1	1	1	1	0	0	0	1.46	0.17	0.0002	0.4153	0.0717
350	1	3	3	6	0	15	2	0	2	2	4	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	0.92	0.12	0.0002	0.2596	0.0448
351	1	2	2	6	0	12	2	45	2	2	4	0	0	0.05	0	0	4	1	1	1	1	1	1	1	0	0	0	1.23	0.14	0.0002	0.3227	0.0557
352	2	1	1	3	0	10	2	60	2	2	6	0	0	0.05	0	0	2	1	1	1	1	1	1	1	0	0	0	1.56	0.27	0.0002	0.4873	0.0842
353	3	4	3	3	3	20	2	0	1	1	3	0	0	0.05	0	0	6	1	0	0	1	0	0	1	0	0	0	0.96	0.06	0.0002	0.0317	0.0251
354	1	3	3	5	2	15	2	30	2	2	6	0	0	0.05	0	0	5	1	1	1	1	1	1	1	0	0	0	1.23	0.14	0.0002	0.2540	0.0439
355	2	1	1	0	0	7	2	60	1	1	3	0	0	0.05	0	0	2	2	1	1	1	1	1	1	0	0	0	1.83	0.19	0.0002	0.8082	0.1213
																												1.455	0.11	0.0002	0.207	0.052

Combined Report for final

00:06:24		Monday	February	13	2006		
Goal Level	Decision Variable	Solution Value	Unit Cost or Profit c(j)	Total Contribution	Reduced Cost	Allowable Min. c(j)	Allowable Max. c(j)
G1	X1	0	0	0	0.00	0.00	M
G1	X2	198,520.41	0	0	0	0.00	0.00
G1	X3	161,979.59	0	0	0	0.00	0.00
G1	X4	0	0	0	0.00	0.00	M
G1	X5	355,500.00	0	0	0	-M	0.00
G1	X6	179,000.00	0	0	0	-M	0.00
G1	X7	0	0	0	0.00	0.00	M
G1	X8	0	0	0	0.00	0.00	M
G1	X9	0	0	0	0.00	0.00	M
G1	X10	0	0	0	0.00	0.00	M
G1	X11	0	0	0	0.00	0.00	M
G1	X12	0	0	0	0.00	0.00	M
G1	X13	0	0	0	0.00	0.00	M
G1	X14	0	0	0	0.00	0.00	M
G1	X15	60,000.00	0	0	0	-M	0.00
G1	X16	0	0	0	0.00	0.00	M
G1	X17	0	0	0	0.00	0.00	M
G1	X18	0	0	0	0.00	0.00	M
G1	X19	0	0	0	0.00	0.00	M
G1	X20	790,000.00	0	0	0	-M	0.00
G1	X21	0	0	0	0.00	0.00	M
G1	X22	0	0	0	0.00	0.00	M
G1	X23	0	0	0	0.00	0.00	M
G1	X24	0	0	0	0.00	0.00	M
G1	X25	0	0	0	0.00	0.00	M
G1	X26	120.00	0	0	0	-M	0.00
G1	X27	0	0	0	0.00	0.00	M
G1	X28	0	0	0	0.00	0.00	M
G1	X29	0	0	0	0.00	0.00	M
G1	X30	0	0	0	0.00	0.00	M
G1	X31	0	0	0	0.00	0.00	M
G1	X32	0	0	0	0.00	0.00	M
G1	X33	127,000.00	0	0	0	-M	0.00
G1	X34	0	0	0	0.00	0.00	M
G1	X35	0	0	0	0.00	0.00	M
G1	X36	0	0	0	0.00	0.00	M
G1	X37	0	0	0	0.00	0.00	M
G1	X38	33,000.00	0	0	0	-M	0.00
G1	X39	0	0	0	0.00	0.00	M
G1	X40	0	0	0	0.00	0.00	M
G1	X41	0	0	0	0.00	0.00	M
G1	X42	0.07	1.00	0.07	0	0.57	5.97
G1	X43	0.17	1.00	0.17	0	0.95	2.04
G1	X44	0.02	1.00	0.02	0	0.28	5.26
G1	X45	0.08	1.00	0.08	0	0.14	1.04
G1	X46	0.09	1.00	0.09	0	0.14	1.04
G1	X47	0.33	1.00	0.33	0	0.44	1.36
G1	X48	0.89	1.00	0.89	0	0.96	1.89
G1	X49	0.31	1.00	0.31	0	0.53	2.47
G1	X50	0.32	1.00	0.32	0	-0.43	1.50
G1	X51	0.07	1.00	0.07	0	0.66	7.00
G1	X52	0	1.00	0	2.00	-1.00	M
G1	X53	0	1.00	0	2.00	-1.00	M
G1	X54	0	1.00	0	2.00	-1.00	M
G1	X55	0	1.00	0	2.00	-1.00	M
G1	X56	0	1.00	0	2.00	-1.00	M
G1	X57	0	1.00	0	2.00	-1.00	M

Combined Report for final

G1	X58	0	1.00	0	2.00	-1.00	M
G1	X59	0	1.00	0	2.00	-1.00	M
G1	X60	0	1.00	0	2.00	-1.00	M
G1	X61	0	1.00	0	2.00	-1.00	M
G1	Goal	Value	(Min.) =	2.35			

Constraint	Left Hand Side	Direction	Right Hand Side	Slack or Surplus	Allowable Min. RHS	Allowable Max. RHS	ShadowPrice Goal 1
C1	1,215,000.13	=	1,215,000.00	0	-M	3,107,179.00	0.00
C2	575,000.00	=	575,000.00	0	524,208.69	M	0.00
C3	1,805,000.00	=	1,805,000.00	0	1,787,922.00	M	0.00
C4	1,905,000.00	=	1,905,000.00	0	1,743,140.38	M	0.00
C5	0.00	=	0	0	-M	161,979.59	0.00
C6	1,217.73	=	1,217.70	0	820.66	M	0.00
C7	1,419,000.00	=	1,419,000.00	0	297,477.75	M	0.00
C8	239,000.03	=	239,000.00	0	-M	626,210.13	0.00
C9	0.00	=	0	0	-M	14,866.38	0.00
C10	86.27	=	86.27	0	-M	1,066.71	0.00
C11	895,000.00	=	895,000.00	0	733,020.38	913,975.56	0.00
C12	60,000.00	=	60,000.00	0	0	79,916.41	0.00
C13	790,000.00	=	790,000.00	0	91,897.19	809,434.63	0.00
C14	120.00	=	120.00	0	0	17,197.99	0.00
C15	127,000.00	=	127,000.00	0	0	146,593.88	0.00
C16	33,000.00	=	33,000.00	0	0	52,593.87	0.00
C17	179,000.00	<=	179,000.00	0	0	340,859.63	0.00
C18	0	<=	1,558,000.00	1,558,000.00	0	M	0
C19	711,000.00	<=	711,000.00	0	0	1,034,719.25	0.00
C20	2,572,000.00	<=	2,572,000.00	0	1,404,700.00	3,523,734.50	0.00

List of Publications/Presentations

[1] Deshmukh M. K., Deshmukh S. S. Optimal renewable energy model for rural end-uses. XVI National Convention, Indian Association of Physics Teachers, Yavatmal. 2001.

[2] Deshmukh M. K. and Deshmukh S. S. Wind power generation option for ABT affected power producers. International Conference on New Millennium - Alternative Energy Solutions for Sustainable Development, PSG College of Engineering, Coimbatore. 2003; 398-402.

[3] Deshmukh M. K., Deshmukh S. S., Roy G., Gopal M. V. Regional level energy resource allocation by using goal programming technique. National Conference on Mathematical Modeling and analysis, BITS, Pilani. 2004.

[4] Deshmukh M. K., Deshmukh S. S. Micro-level Integrated Renewable Energy System Planning in India. National Conference on Energy Management in Changing Business Scenario at BITS, Pilani. 2005.

[5] Deshmukh M. K., Deshmukh S. S. Optimum Size of Wind, Photovoltaic and Hybrid Wind/PV Power Generation System for Region in Rajasthan. National Conference on Energy Management in Changing Business Scenario at BITS, Pilani. 2005.

[6] Deshmukh M. K., Deshmukh S. S. Micro-level Integrated Renewable Energy System Planning in India. Energy and Fuel Users Journal. 2006 (Accepted – In press).

[7] Deshmukh M. K., Deshmukh S. S. Optimum Size of Wind, Photovoltaic and Hybrid Wind/PV Power Generation System for Region in Rajasthan. Energy and Fuel Users Journal. 2006 (Accepted – In press).

[8] Deshmukh M. K., Deshmukh S. S. A New Approach to Micro-level Energy Planning. Renewable Energy (Communicated).

[9] Deshmukh M. K., Deshmukh S. S. Micro-level Integrated Renewable Energy System Planning – a Case of Northern Parts of Rajasthan, India. Renewable Energy (Communicated).

[10] Deshmukh M. K., Deshmukh S. S. Household and Agriculture Energy Consumption Patterns in Northern Parts of Rajasthan, India. Energy Education Science and Technology (Communicated).

Brief Biography of the Candidate

Sandip S. Deshmukh did his B.E. in Mechanical Engineering and M.E. in Thermal Power Engineering from Amravati University, Maharashtra. He has been working as a Lecturer in Mechanical Engineering Department of Anuradha Engineering College, Chikhli, Amravati University, Maharashtra for five years. He took up teaching and research in Renewable Energy Planning and dissemination from 2000 at Birla Institute of Technology and Science (BITS), Pilani. He has also taught various courses for distance learning programmes of BITS, Pilani in the area of Energy Management and Mechanical Engineering. He is involved in conducting a number of training programmes to professionals of MNES/SNA at BITS, Pilani and ENFUSE, Chennai in the area of renewable energy, energy planning, energy conservations and energy management.

Brief Biography of the Supervisor

Prof. M. K. Deshmukh did his M.Tech and Ph.D. in Renewable Energy Management from the Indian Institute of Technology, Delhi. He served in the field of renewable energy field in India in various capacities for the past two decades. He has been on the empanelled as senior member of Association of Energy Engineers, USA. He has been Deputy Director, Centre for Energy Studies and Research at Devi Ahilya Vishwavidyalaya at Indore for 10 years. He has 20 years of distinguished professional, administrative and academic experience. He has been coordinator of Centre for Renewable Energy and Environment Development (CREED) at BITS, Pilani for implementing sponsored projects in Renewable Energy. He has published extensively on renewable energy policy and planning. He is actively engaged in energy education, resource development and training activities in the field of renewable energy. His areas of research are integrated renewable energy systems, energy policy and planning, energy management and conservation, and power systems. Presently, he is Associate Professor in Electrical Electronics Engineering and Faculty In-charge Administration of the BITS, Pilani-Goa Campus.