1 Inclusion and treatment of the rural sector in energy models

Sohini Sahu, Research Associate, TERI, New Delhi

Abstract

Energy planning has now become an inalienable part of aggregate macro level planning. Rural energy planning per se` becomes an important issue in a developing country like India. This paper investigates the extent to which the rural sector has been included in the various energy models used in India, especially the ones used by TERI. Alongside the modelling exercises carried out, the paper also touches upon the survey-based rural planning methodology adopted by the agency(ies) which are responsible for energy planning at the micro level of the economy. Apart from giving a briefly describing the energy models in terms of the nature of data required, the assumptions and the results as far as the rural sector is concerned, the paper also attempts to evaluate the effectiveness of the same, thereby identifying the aspects of improvement in rural energy planning.

Introduction

Even after fifty years of independence, it is true that 'India lives in its villages'. A whopping 70% of the country's population lives in rural areas, spread over 580,000 villages. This rural populace is primarily engaged in agriculture whose contribution to the gross domestic product was 27% in 1999/2000 at 1993/94 prices.

Given the overwhelming size of rural India, it has been stressed time and again that a holistic view of development cannot turn a blind eye to this sector. It has been well realized that development related activities cannot remain confined to the industrial and the urban centres only, the rural centres provide the missing link to the path of overall developmental goals.

These rural areas are typically characterized by low standards of living, an outcome of low employment opportunities coinciding with poor incomes, since agricultural activities are gradually sliding and employment has reached a saturation level. This has led to a huge influx of a proportion of the rural inhabitants to the urban centres, as suggested by the Harris-Todaro model of migration. The irony is that, even these urban regions cannot absorb these migrants productively, employment openings being the main constraint. Hence, a large section of these burgeoning migrants become faceless workers in the informal sector. With formal sector jobs becoming elusive, these people ultimately end up in a situation where they are marginally better off or at times even worse than their preceding village lives.

This drives home the fact that a conducive situation should be created which can absorb the rural people productively at their own village, thereby contributing significantly to rural activities and reducing the pressure on the urban centres simultaneously. In order to achieve this, priority should be given to rural development encompassing all the related sectors like infrastructure, energy, communication, health and education.

The role of energy in this entire exercise is crucial. It is a factor, which either directly or indirectly, plays the lead in developmental activities. Take for example agriculture, which is still the dominant employer of the rural masses. Switching over from animal energy to tractors, from manual watering of fields to irrigation pumps and from informal storage houses to cold storage, can significantly increase agricultural productivity, and agro-processing might also emerge as a potentially viable income/employment facet.

Very few villages have activities after sundown. The dimly lit shops in the marketplaces represent another lost opportunity. With electric lighting and cold storage facilities, you need not be an expert to predict the changes it can usher in. Marketplaces would be the centre of all activitiy, thereby opening up another income/employment opportunity.

Next, take the case of the present living standards in the rural households. The households remind you of dark, dingy and smoky indoors, where women spend the better half of their lives cooking and catering to the needs of the infants at the same time. Biomass fuels serve 85% to 90% of household energy needs, and bring along a host of health hazards, especially for women and children; indoor pollution and a significant opportunity cost.

Even the educational and health aspects are contingent on the availability of energy. While electric lights replacing the open- wick kerosene lamps might not be a welcome change for those who want to evade studies, nevertheless it is more effective, hygienic and less detrimental to the vision. On the other hand, the ability to tackle emergencies at night and the storage of vaccines and life- saving drugs at the local village health centres would be enhanced in the presence of modern energy carriers.

A patchwork of typical village life has been sketched above, only to emphasize the point that energy is the keyword and it is the one aspect that can integrate all the other related development activities. Providing modern energy arbitrarily would not suffice, it is not the target; it is just the starting point. Each rural area has its own distinct features and the energy requirements of two villages would never be alike. A complete study of the existing energy endowments, the feasibility of alternative energy forms, the methods of financing the switch over and the concomitant reshaping of the institutions and people's the psyche will form the integral parts of effective rural energy planning.

Rural energy planning agency(ies) in India

Economic agents in any given geographical area use a combination of traditional and/or commercial fuels to satisfy their energy needs. The basket of fuels they choose is driven by their individual objective function, like utility maximization or of the consumers surplus maximization or cost minimization. The objective of planning is either to maximize the total social surplus or to obtain an economy-wide cost-minimized basket of fuels. The success of any such macro/ micro- level planning lies in the method of integrating a broader objective with individual objectives such that the micro agents ultimately end up using efficient forms of energy, as desired by the planning exercise while satisfying their respective objective functions.

The IREP (Integrated Rural Energy Programme) was developed in the Seventh Five -Year Plan period when projects were set up in various agro-climatic zones in India, for decentralized rural integrated energy planning at the most micro level , i.e., at the block level. The broad objectives of the IREP encompass the provision of energy for meeting the basic needs of cooking, heating, and lighting using locally available resources.The promotion of renewable energy sources and the efficient use of the non-renewable ones are important parts of the agenda of the IREP along with capacity building for greater co-ordination, participation and involvement among the stakeholders. Rural energy planning in India comes under the ambit of the MNES (Ministry of Non-conventional Energy Sources) which has been assigned the implementation of the IREP.

The MNES is the nodal agency of the Government of India which deals with all the matters relating to non-conventional/ renewable energy covering the policy – making , planning, promotion and co-ordination functions. These include fiscal and financial incentives, creation of industrial capacity, promotion of

demonstration and commercial programmes, Research and Development and technology development, intellectual property protection, human resources development and international relations.
(Source: www.indiasolar.com/MNES-PROFILE.htm)

IREP has been integrated with a greater objective of rural development. In general, the government's programmes on rural energy fall within the following four broad areas:

	Theme	Responsible Ministry (ies)
1.	Forestry	Ministry of Environment and Forests Ministry of Rural Areas and Employment
2.	Rural Electrification	Ministry of Power
3.	Renewable Energy	Ministry of Non Conventional Energy Sources (MNES) Ministry of Power (for large capacity)
4.	Area based programmes	Ministry of Non Conventional Energy Sources (MNES)

Source: UNDP (http://www.undp.org.in/programme/rrlenrgy/rengobj.htm)

The energy planning methodology for the IRDP was assigned by the MNES to TERI for three different agro-climatic areas - Mandla in Madhya Pradesh, Ladakh in Jammu and Kashmir and North Tripura. The following passage depicts the planning exercise undertaken by TERI on behalf of the MNES

Rural energy planning methodology at the district level

The Department of Non-conventional Energy sources following the workshop on "*Decentralised Rural Energy Planning and Implementation*" held at Nagpur in 1989 sponsored a number of energy planning studies in various districts of different agro-climatic zones. The study undertaken by TERI at Mandla district in the tribal - dominated areas of Madhya Pradesh was the first of its kind, which focused exclusively on rural energy planning at the district level. In the process the study formulated methodologies to handle different components – demand, supply and the development and management of the energy plan 's implementation.

This section deals with the details of the methodology followed in the process of outlining an energy planning framework. A somewhat similar approach was followed in the two subsequent energy planning exercises carried out by TERI in Ladakh and Tripura on behalf of the MNES.

A broad overview of the methodology followed by TERI for district - level energy planning:

The broad objective of energy planning encompasses a methodology for rural energy planning at the district level to arrive at a feasible mix of energy sources – conventional and non-conventional that can meet energy needs by keeping in view the development priorities of the district. Fulfilling this objective requires an understanding of the profile of the relevant district, which constitutes the physiography, climate, area and population, land- use pattern, agriculture, livestock population, infrastructure and energy consumption. All this information was collected from the Census Handbook of the district under analysis.

Energy supply

While carrying out the energy planning exercise, it is imperative to have a proper estimate of the energy presently available from various sources , which meet different energy end-uses in the district. This would help in arriving at a realistic supply scenario so that the energy demand and supply could be properly matched for use of the energy plan. The methodology followed in this context was not a mere assessment of the existing supply scenario but delved into other aspects, such as non-energy uses of these sources and the management practices and functioning of the organizations involved in their management.

Wood biomass assessment

Given that rural India's energy needs are fulfilled by biomass , the initial step was to evaluate the present sources and nature of supply of woody biomass. A realistic assessment of the existing stock of woody biomass is required to study the stress on the resources due to energy and non-energy uses Hence, an assessment of the forest resources in the district was carried out to study the growing stock from forests of the district, estimate sustainable yield from the growing stocks, the present pattern of woody biomass consumption and the potential use of woody biomass for energy generation and suggest measures to improve the management of forest resources.

The above study- related information was collected from the Forest Department's documents and discussion with officials. The working Plans, Working Schemes and the Annual Administrative Reports from the Conservator's Office were the sources of secondary data related to the history of the forests in the district, the growing stock, sustainable yields, local rights and privileges, popular practices, the area of the forests, the volume of wood harvested, the extraction of minor products, development programs etc. The Timber account, return of Transit Permit and results of auctions from the Divisional Forest Officer's Office threw light on issues like the quantity of wood movement, aggregated stock situation in depots, and revenues realized . At the Range Office, the case diary register and the beat reports gave a clue to the extent of illegal felling, encroachments, incidents of fire and thefts. Details on wood production similar to timber accounts, growing stocks, volume tables, regression equations etc. were available from the Report of Forest Survey of India and other reports published by production division.

The secondary data however had limitations which are listed below:

- The data was mainly available in terms of geographical areas and not in volume, which is essential for assessing biomass resources.
- The data on growing stocks, annual yields and expected yields were all in area terms and since no data were available on the cropping density, crop height or crop diameter for the same area, estimation of the volume was not readily possible.
- The information was highly scattered over several offices, making it tedious and cumbersome to compile all the necessary data.
- The records in valuable sources like the Nistar and Beat Reports were incomplete and faulty thereby reducing the reliability of data.

A primary survey was carried at the village level to understand the status of woody biomass in the sample villages since common and private non- forest land also constitute a source of woody biomass. The inclusion of this source is relevant to get an estimate of the total woody biomass available. Thus, an inventory was planned for the woody biomass standing on these land categories in both FV (forest villages) as well as RV (revenue villages). To select the villages for the proposed survey, forest as a percentage of the total land of the village was taken as the criterion since it was an indicator of relative availability of biomass and the stress on biomass. The procedure adopted constituted of listing the village-wise data on forests as a percentage of total land and grouping the villages into four strata with ranges of 0-15%, 15-30%, 30-45% and 45-60%. A total of 12 villages were selected in that manner.

Animal Waste

Availability of animal waste depends on the cattle population ,and the feeding and the grazing practices. Data on block-wise availability of wet as well as dry dung based on the cattle population was available from the Veterinary Department. A Primary survey revealed the extent of energy use and non-energy use of animal wastes.

Crop Residues

The grain-to-residue ratio typically varies depending on the nature of seeds, soil character and the amount and time variation of water availability necessary for crop growth. A Summary of the residue estimates from different crops were computed from myriad data sources like NPC, IAE, FAI, ICAR etc.
Data problems arose in estimating the proportion of crop residue used for fodder and thatching vis-a vis` energy requirements.

Kerosene

This is the primary commercial fuel still used in the rural areas of India. In order to estimate the accessibility of this fuel in the rural areas, the distribution system for kerosene and the organizations involved in the distribution were studied with special focus on the efficacy of the existing system. For this, extensive discussions were held with the district/ divisional level authorities/ agencies involved in kerosene distribution with the help of structured questionnaires. In addition , a primary survey was carried out to study the overall energy consumption pattern in the district.

Electricity

The management of electricity supply is done by a co-operative set-up, the *Grameen Vidyut Sahakari Samiti,* which for all purposes is controlled by the MPEB. Since electrification of a village does not automatically indicate that electricity is supplied to all the households, primary surveys were conducted to get a clue on the electricity consumers in households as well as the energization of pump sets.

Energy demand

The specified energy demand for different end- uses may either be based on an energy survey to determine the existing energy consumption or a normative value, based on predetermined criteria. In both cases, the relevant measure would be the useful service provided. The relevant unit for specifying the demand depends on the end-use and is generally one of the following - acre of land, tonne of produce etc. and a procedure for aggregating the demand at the appropriate or desired administrative level is required thereafter.

In TERI studies however, primary surveys were carried out with an emphasis on the major existing end uses in the districts namely cooking, lighting, irrigation et al.

Methodology

In order to aggregate energy demand at a higher level, it is crucial to select the statistical sample with acute precision.

Sample selection

In the context of the variety of items on which information is sought through a survey for local energy planning, the selection of sample is a complex task. For energy demand estimation, aggregation and projection, it seems desirable to select sample villages based on

1. per capita forest land
2. per capita agricultural land
3. per capita cultivable wasteland and
4. per capita livestock population

It is assumed that these parameters reflect the stress/ availability of biomass energy resources on which the village energy system is based and for economies based on agriculture, land would serve as a proxy for income. In addition to the per capita land availability, the variation in the productivity of land must also be incorporated in the exercise of constructing the strata using per capita land. The appropriate sample selection criteria to determine the pressure on agricultural land require consideration of the productivity of soil; the logical method to do this would be to scale the per capita land availability by the productivity. However, in the absence of clear geographical demarcations of land productivity, and the fact that for a significant sample size post- stratification is as accurate as pre- stratification (Cochran 1977), post stratification of this category can be used as a statistically acceptable option.

Formation of cluster of villages:
The procedure for identifying the clusters with a particular characteristic consists of listing the village-wise per capita data of the above-mentioned land use categories (agricultural, forest and culturable wasteland). From this data, a list of contiguous villages (denoted by sequential census numbering) satisfying conditions of low and high per capita land can be grouped into clusters for which, say 80% of the villages must satisfy the criteria for the " low" or " high" classification. Villages can then be randomly selected from within the clusters as well as outside the clusters so as to be statistically representative.

Sample selection methodology
The following list contains some of the practical considerations which are required for cluster formation prior to the survey and the actual selection of villages for the survey :

1. The limitation of considering per capita land without considering the productivity of land is a shortcoming of using per capita agricultural land as a criterion for cluster formation. Usually the most agriculturally prosperous villages do not correspond to the villages with high per capita agricultural land; the converse is often true. Hence, while selecting the clusters, the land productivity should also account in some form.
2. A particular problem arises with respect to the Forest Villages. The formation of forest villages occurred in the late 1970's when the Forest Department leased agricultural land to households on forestland. As a result of being situated at the forest fringes, these villages had access to the forest resources as well and kind of depended on them to a very large extent mainly due to the fact that the leased lands were of low quality and unsuitable for agriculture. The leased plots however were large in size, thereby indicating high per capita agricultural land whereas the predominant characteristics of these villages is easy access to biomass.
3. Although it is desirable to incorporate per capita livestock population in the sample selection procedure through the formation of clusters, very often-non availability of data defeats the objective.

It would be worthwhile to look into the above and then evolve a general methodology replicable at the district level.

Survey instruments

Structured questionnaires were used as survey instruments and had two components- village schedule and household schedule. The design of the questionnaire took place in two stages: detailed questionnaires were designed for the village and households, administered in few villages and in the second stage; they were modified on the basis of the first survey. The process of addition or deletion of questions was guided by the desire to avoid situations in which, to quote Robert Chambers,

"*Much of the material remains unprocessed, or if processed, unanalysed, or if analysed, not written up, or if written up, not read, or if read, not remembered, or if remembered, not acted upon.*"

(Chambers 1983:53)

The final version of the questionnaire therefore is brief and contains information selected with care , to be relevant for the purpose.

Survey results

The data that was collected through the interviews based on the questionnaires were compiled on master sheets, computerized, processed and then analysed. The statistical properties of the concerned variables were summarized and tabulated. The analysis was directed towards examining the statistical distribution of the collected data and unlike previous rural energy surveys where the normal distribution was assumed; an effort was made to find alternative distribution functions which were more relevant to the information collected.

Energy demand

For the purpose of planning, there are at least two basic information requirements: the demand aggregate in the region relevant to the planning exercise and the projection of future demands over the planning horizon.
The aggregation of energy demand was deduced from the distribution of the consumption of biofuels which had been computed already. This was then aggregated to the useful energy demand provided by the biofuels.
Demand projections require good knowledge of the explanatory variables affecting energy demand. As a first approximation, the population is the dominant factor in the change of energy consumption over time. The population projections were based on the growth pattern evident from the census records.

Development priorities

Often in the past, the development priorities of the region have not received adequate attention while conducting energy planning exercises. The result was that the suggested energy interventions could not be appropriately integrated into the overall development strategy and thus failed to succeed. The success of any energy planning exercise lies in designing energy schemes which are congruent with the needs and the perceptions of the people who are supposed to be the direct beneficiaries.

Implementation

A Proper management system, or the lack of it, has been one of the major shortcomings in the implementation of energy plans in the past. Therefore it is imperative to design an appropriate management system to ensure successful implementation of the proposed energy plan.

Lessons learnt

Though similar techniques of energy planning were adopted, the outcomes varied largely depending on geographic location, resource endowments and the technological feasibility of providing commercial energy to these places.

In the tribal- dominated region of Mandla in Madhya Pradesh the planning exercise indicated efficient use of available biomass resources, while in the hilly regions of North Tripura the stress was more on renewable sources like biomass gasifiers, solarphotovoltaic lighting systems and mini-micro hydel power systems for power generation due to the intersection of hilly rivers in the region. Similarly, the prescription for the mountainous regions of Ladakh constituted renewable sources due to the abundance of sunshine, wind and streams and the technological infeasibility of providing commercial sources of energy to such remote and sparsely populated areas.

The three case studies exemplify the fact that given the diverse features of rural India, a simple stock planning exercise cannot be the solution. The objective of energy planning should not only be integrated with the larger goal of overall rural development, but should be exclusive for each region. This requires time, manpower, management and expertise from the planning agency. If each region is to be scrutinized to evaluate its energy status, then a huge army of trained personnel is required to carry out the detailed surveys and analyze the results. Coupled with such efforts, the agency or the body carrying out the exercise should also be assured of ready cooperation from the district offices and all the stakeholders, so that maximum and accurate data is available within a reasonable time period. And lastly, there should be adequate budget allocation so that funds are available to carry out such extensive and expensive exercises.

This also throws light on the economic reality that since the planning exercise involves multiple parties, the underlying incentive structure of each of the participants should be very strong and compelling. If the incentive structures are well defined and in lines with the objectives of each of the stakeholders, then maximum participation and cooperation among them can be ensured.

So, if on one hand we have survey-based energy planning, on the other hand there is the option of sophisticated mathematical energy modelling. The need for such modelling arose after the first oil embargo in mid 1970's and ever since the US has taken up modelling as an integral part of its national energy planning, while the developing countries including India have not lagged behind in this respect.

Why energy modelling

Traditionally, energy planning has been a part of macro-economic multi-sectoral projections, but with the beginning of the era of liberalization in mid eighties, it was felt that energy planning required a niche of its own to provide strategies for optimising the efficiency of the growth process by reducing the energy cost of the economy (Sengupta. R, Planning Commission, New Delhi 1993). Mathematical modelling emerged as a feasible technique which allows handling of myriad energy-economy variables and data, along with the comprehensive coverage of all the energy sources, uses and sectors, which are all enmeshed together in order to develop a criterion of choice which would be objective, quantifiable and capable of systematically reflecting changing situations and priorities((Sengupta.R, Planning Commission , New Delhi 1993).

Ideally, a model is based on a series of assumptions and inter-relations between various quantitative and qualitative variables, expressed mathematically so that the effect of a change in one variable or more variables on the system as a whole becomes evident. Energy models broadly fall under two categories: top down and bottom up. The former are characterized by aggregate, economic parameters, along with the consumption choices of the consumer, technology. And the relationship between the factors of production within the firms. These relationships explain how the relative use of inputs will change in response to changes in their relative costs and how the relative consumption of goods and services will change in response to changes in their relative prices. On the other hand, the bottom up models describe the economic system from the perspective of equipment, energy and sometimes labour and material output. They miss the value added component of many of the service sectors with minor energy changes. An integrated model combines both of the above, where in the results of each module feed into each other, in the process fine-tuning the model.

Different energy models in TERI and the extent to which they incorporate the rural sector

To assist in policy analysis, TERI has developed/used three energy modelling exercises. The TEESE model and the MARKAL model are macro level models encompassing all the energy supply and demand sectors of India and include the rural sector to the extent of its contribution in energy demand from the perspective of agriculture and households. Thus, rural India features as one of the component sectors of the models since the focus remains on economy wide energy planning.

One micro level model was developed by TERI in the late 1980’s, which concentrates only on rural energy planning and hence takes into consideration the nitty-gritty of rural energy supply and demand factors.

As in the following pages we go through the models and see the extent to which they take into account the rural sector, one thing clearly stands out in the process. While survey and case study based energy planning are the best approximations of the ground realities, they do not provide an opportunity to carry out comparative static exercises typically constituting of ‘if-then’ situations. Modelling compensates for this disadvantage as it allows for evaluating alternative energy policies/scenarios in the wake of new technologies or price regimes and their impacts on other macro-economic variables. As we go through the synopsis on the energy models used by TERI, this feature becomes all the more evident and promises to be a powerful tool to plan implementation.

The TEESE Model (Teri Energy Economy Simulation and Evaluation Model)

The TEESE model is a static optimisation macro-model consisting of three separate modules: the RES (Reference Energy System), an Input/Output model, and a LP (Linear Programming) framework. The model aims to integrate the energy supply and demand considerations and study the end use energy demand patterns of various sectors, in the process of minimizing system cost of energy and energy - utilizing activities.

This model takes into account 10 primary energy sources, 15 secondary energy sources and about 43 non-energy sectors. The rural perspective that is present in the model comes from the agricultural sector and the domestic sector.

In the agricultural sector, the two energy- intensive activities are land preparation and irrigation.

In case of irrigation, the water requirement of different crops have been taken into account along with the percentage of crop being irrigated by pumps. On the basis of this, irrigation requirements in cubic metres of water per rupee output of crop have been estimated. The efficiencies of the pump sets, electric and diesel have been measured in terms of the units of energy required per cu.m. of water pumped out under the assumptions of average pump size, efficiency etc.

The demand for energy for land preparation has been calculated on similar lines. The crop wise land preparation demand has been estimated, taking into account the sources of meeting such demand viz. tractors and animal power. Along with the energy content, the time factor too has been considered explicitly in terms of tractor hours of work and animal pair days of work.

The domestic sector, which is one of the primary energy, demand sectors has been further disaggregated into urban and rural components. End uses relating to the domestic sector: lighting, cooking, water heating, refrigeration, Television loads and the use of fans have been worked out based on the energy-norms of these energy services. The demand for these uses is categorized for different income classes in the urban and the rural population. NCAER's (National Council for Applied Economic Research) domestic fuel survey with special reference to kerosene serves as the data source for consumption norms of different forms of energy for various end uses and income classes.

Sample results from the model (rural focus only)

This model was first validated for the year 1984-85 and run for the year 1989-90 to estimate energy demands by using the final demands vector projected by the Planning Commission in the technical note to the Seventh Five -Year plan and assuming that technology would remain more or less constant over these 5 years.

In the base case scenario, assuming a rate of growth of 15% in tractor population over the 5 year period from 1984-85, it was found that all tractor capacity was being used (2.14 MT of diesel) up with a residual demand of ten million head of cattle for land preparation. The irrigation water demand was estimated at 440 billion cu.m assuming that 66% of rice production would be from irrigated areas by 1989-90 and that 80% of wheat would be irrigated as per 7^{th} Plan document. The demand for diesel for irrigation purposes was estimated at 2.86 million tones.

All of the traditional forms of energy were consumed within the domestic sector- approximately 95 million tones of animal dung, 43 million tones of crop waste and 63 million tones of firewood. The Seventh Five-year plan document had estimated firewood availability in the year 1989-90 at only 50 million tonnes.

However, the estimates for domestic sector showed 26.8 TWh of electricity were consumed for lighting purposes and 6.8 TWh in the use of fans, 9.9 million tonnes of kerosene and 830000 tonnes of LPG. These estimates are not disaggregated for the urban and the rural household sectors.

Apart from the base case scenario, alternative scenarios were also attempted to capture the fallouts of a 10% shortfall in electricity, 20% shortfall in electricity and a 10% shortfall in electricity with oil consumption pegged to 1985-86 level.

As is evident from the results of the model, though rural energy planning cannot be addressed exclusively as the rural economy falls within the greater set of the macro-economy, this modeling exercise gives a precise clue to how different policy scenarios would influence the rural sector. A change in policy at the highest level of the economy like decisions to peg oil imports or use more renewable energy, will have concomitant effects on the availability of fuels to the rural sector. To that extent, this model can serve the purpose of providing insights into rural India's energy scenario.

The MARKAL Model at TERI

The MARKAL or the Market Allocation Model, which is the present energy model in use at TERI , bears resemblance to the TEESE model save the fact that it is a dynamic modelling exercise. The Indian MARKAL has been designed with 1996-97 as the base year and consists of a 45-year timeframe. The model allows for identification of the key technologies for promoting environmentally responsible sustainable development and the evaluation of the implications of global climate change deliberation and policies in addition to its primary objective of deciding on the least cost fuel mix for the economy.

Apart from the inclusion of the agricultural sector and the rural domestic sector, the model encompasses non-commercial or traditional energy forms on the supply side to capture a unique feature of developing economies. Hence, unlike most energy balances, this model incorporates both the commercial and the non-commercial energy forms.

Presence of the rural sector in this model

Like the TEESE model, the agricultural and the rural residential sectors find their place in the demand side. On the supply side, traditional fuels now find a place as fuelwood, dung and crop residues are included in the optimisation exercise.

The supply figures of fuelwood are provided by the Integrated Rural Energy Program (IREP), 1992 and the future estimates are based on the forecast figures of area under forest as in DISHA[a] (Directions Innovations And Strategies For Harnessing Action For Sustainable Development) 2000.

Data on the availability of animal residue is not available and is calculated indirectly using the cattle population, the proportion of dung collected and the shared use for energy purposes. Similarly, in the absence of data on crop residues, the quantum is calculated indirectly from the proportion of total crop available as fuel.

Under the alternative assumptions of 6% and 6.5% growth of GDP (Gross Domestic Product) along with the population forecasts and the urbanization index available from the projections of the Planning Commission, the model was run and validated for the base year 1996-97. With satisfactory outcomes for the base year, the model indicates a gradual decline in the net availability of biomass resources from 276.14 MT in 1996-97 to about 242.2 MT in 2011/12. From the demand perspective, going by the model outputs, the kerosene consumption in agriculture would escalate from 1 MT in 1996-97 to 4.56 in 2010-11, while power consumption in the same sector would show a rising trend from 280.4 TWh to 533.09 TWh in the similar time frame. Since the model output for energy demand figures in the residential sector gives the aggregate of both the urban and the rural centres, one needs to cull out the rural component to get a hint of energy consumption in the rural domestic sector.

Notes of caveat:

The above models are optimisation models and hence the results available indicate the system cost-minimized numbers which might actually be quite different from reality. For the base year or years already elapsed, one can validate the model by imposing the institutional restrictions reigning in the economy, thereby indicating the extent to which they diverge from the optimal values.

Secondly, the estimation of energy demand is exogenous to the models. They are typically estimated using econometric methods, and the results obtained

[a] Directions Innovations And Strategies For Harnessing Action For Sustainable Development , TERI 2001

thereafter are fed into the models. So one should keep in mind that MARKAL is not a model to forecast energy demands, it is a model that guides planning by producing optimal results.

In this respect, it can be mentioned that comparison of MARKAL output with those of other models which forecast energy (like the Planning Commission model , i.e. MEEDEs model), is irrational.

A Rural Energy Model for Energy Planning at TERI

Contrary to the two macro level energy models depicted above, there is a micro-level energy-planning model devised in TERI in the late 1980's. It is a village level energy-economy model to identify an optimal mix of centralized/decentralized, conventional/non-conventional energy systems from the point of view of the farmer or social cost-benefit cost analysis.

The optimisation model which is an application of Mixed Integer Programming integrates the database provided by the village level RES. The significance of the model lies in the fact that it focuses on the role of biomass in the village energy planning, thereby incorporating details in its supply and demand structure. The model addresses special problem of a village, related to accessibility and availability of biomass, alternative uses of biomass and the alternative options to biomass.

A pre-tested questionnaire was used to acquire relevant and reliable data from 10 villages in the plain region of Haryana and 10 other villages in the deserts of Rajasthan and then the model outputs are analysed under three scenarios: business as usual (BAU), where only the existing options are considered, scenario 2 where renewable options like biogas plants, PV irrigation system, biomass gasifiers for irrigation, solar cookers, solar hot water systems etc are considered at non subsidized prices, while scenario 3 resembles the preceding one except for subsidized prices attached as cost coefficients to renewable energy technologies.

In all scenarios, cooking, water heating and fodder preparation are met by crop residues. 60% of the lighting demand is satisfied by electricity and the balance met by kerosene in scenarios 1 and 2.In scenario 3, as a result of subsidizing the cost of renewables, biogas for lighting accounts for 36% and kerosene 4%.

Irrigation is totally electricity based in scenario 1 but with introduction of renewable technologies in scenarios 2 and 3, the share of electricity declined to 48.5% and .18% respectively.

A significant point that emerges from the three runs is that the household income does not change significantly with the introduction of renewable energy resources. Subsidization yielded a marginal increase of 0 .4% in average income of household. This result reflects the fact that the villagers have no incentive to switch over from the existing energy systems to the renewable ones. This income encompasses land income only since **paucity of data** prevented the insertion of non-land income.

As the model tries to assist in designing an effective energy plan for the selected villages in Haryana and Rajasthan, planning at a wider perspective should ideally allow for the interaction of the rural sector with the rest of the economy. This integrated approach however requires the following additional data on:

- The geographical characteristics of the area, the soil qualities and the sustainability of different crops.
- The comparative advantages of a particular block in production of certain goods which will determine the kind of industries that might be set up. This in turn might impact the cropping mix.
- Data on the resource endowments and capital stock at the block level, existing demographic details and likely changes in the demographic pattern, impact of socio-economic growth on energy and non-energy requirements etc.

A brief look at the nature of data-use and assumptions in the TERI working model of energy(MARKAL)

As far as the model data requirements are concerned, they can be segregated into the supply side and the demand side components. Taking into account the rural perspective in the model, on the supply side, one needs data on the traditional fuels viz. the fuelwood, crop residues and animal wastes as well as those on commercial energy like kerosene, diesel and electricity used in agriculture and rural residential sectors.

Since MARKAL is the working energy model at TERI, we present below in detail the data requirements, the estimated values and the normative energy consumption figures.

On the supply side:

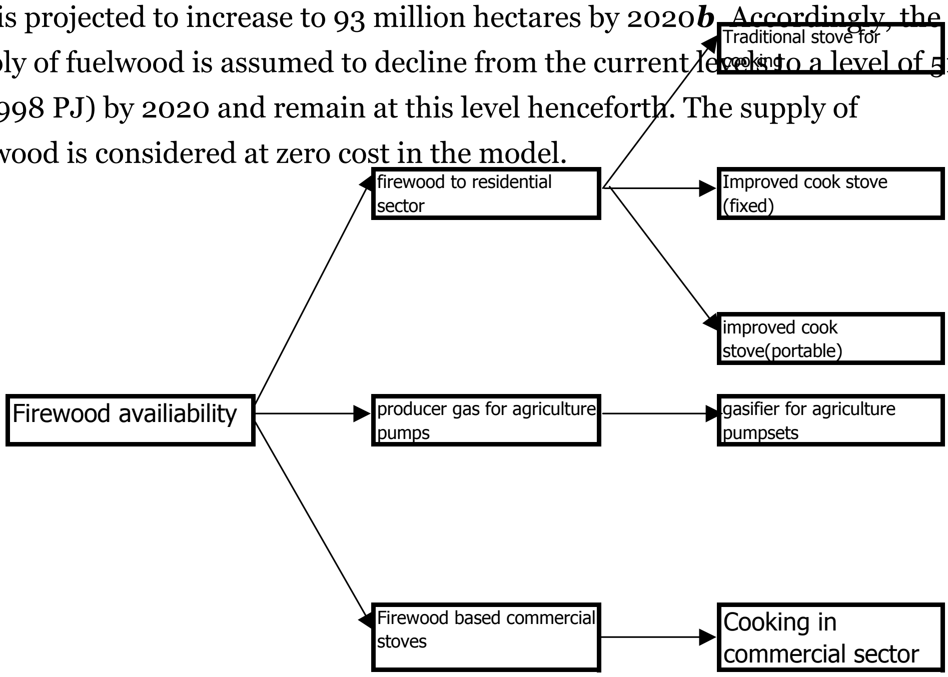
Traditional fuels

Bio-fuels play an important role in the energy scenarios of developing countries. In terms of their use in physical energy terms, bio-fuels constitute nearly the same levels as coal in the country. However, due to the low calorific content of these fuels as well as the low end-use efficiencies associated with their use, the useful energy met by these sources is much smaller.

The Indian residential sector continues to be dominated by the use of bio-fuels, with about 95% of rural households and 40% of urban households still relying mainly on traditional energy forms. All these fuels are generally collected free of cost and do not find their way to commercial markets. Moreover, the supply RES of the traditional energy forms is simplistic and consists of only the domestic availability of the resource, as there are no associated imports or exports for these fuels.

Fuelwood

The supply of fuelwood was estimated at 169 million tonnes (3294 PJ) according to the Integrated Rural Energy Programme (IREP), 1992. However, this level of fuelwood use is considered to be unsustainable in the long-run. The sustainable fuelwood supply is therefore estimated based on future estimates of the area under forests and a sustainable yield of 55 tonnes per square kilometre of forestland. In 1997, the land area under forests was 63 million hectares[a] and this is projected to increase to 93 million hectares by 2020[b]. Accordingly, the supply of fuelwood is assumed to decline from the current levels to a level of 51.2 mt (998 PJ) by 2020 and remain at this level henceforth. The supply of fuelwood is considered at zero cost in the model.

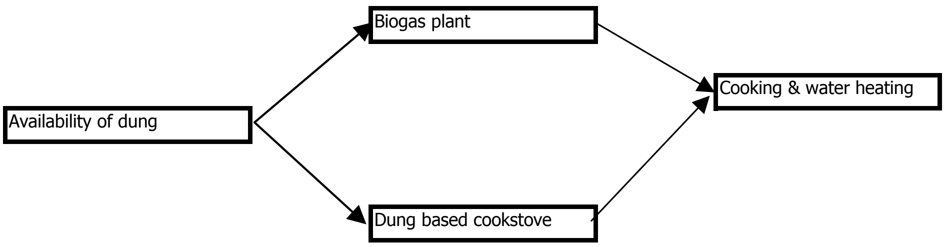


[a] 100 hectares = 1 sqkm
[b] DISHA 2000

Dung

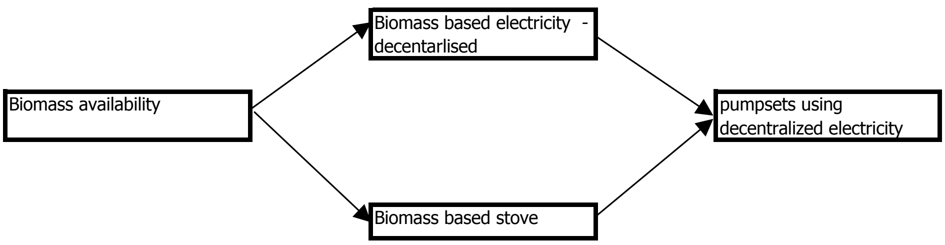
Dung and crop residue are generally used by households that possess cattle or farmlands. Therefore, the issue of unsustainable use of these fuels as in the case of fuelwood does not apply. However, estimates on the availability and use of dung and crop residue vary widely over various estimates.

The supply of dung depends on the cattle population in the country, the proportion of dung collected and the share used for energy purposes. Dung has a calorific value of 3290 kcal/kg. Estimates on the availability of dung range from 30 mt to 100 mt. The model assumes a dung availability of about 100 MT at zero cost. The REDB estimates an average availability of 106.9 mt of dung. The use of dung is therefore really constrained by restrictions on utilization levels of technologies using the fuel and the share of population using this form of energy in the future. Dung can be used directly in the form of dungcakes for cooking in the traditional cookstoves or in the form of biogas, which is a cleaner form of using energy.



Crop residue

Biomass production is pegged at 127 mt/year of which half goes to the sugar industry. With a calorific value of 3500 kcal/kg for biomass, production is kept constant at 912 PJ in the model.



On the demand side:

MARKAL being a macro level model, the rate of growth of population and that of GDP are considered as the two basic drivers of energy demand. In the following sub-section, the source of population estimates and their compatibility with the Planning Commission's estimates are mentioned briefly. The population is segregated into the rural and urban components while both of them are further decomposed into three income classes to capture the varying energy demand across the income categories.

Basic energy drivers

Population

The Population Foundation of India has documented population figures over the past 26 years (1970-1996) and made five-yearly forecasts till 2050. These population projections have been considered with data interpolated for the interim years till 2036.

The total population is categorised into urban and rural population using the urbanisation index (ratio of urban population to the total population) as stated in the census report. The urbanisation index is assumed to increase linearly from a level of 26.9% in 1996/97 to a maximum of 45% by 2036/37. Other studies such as the energy forecasting exercise of the Planning Commission assume comparable levels of urbanisation index for the year 2011/12.

Table 1 provides the estimates of total, urban and rural population in India over the modelling time frame.

Table 1 Population forecasts 1996/97 – 2036/37

Years	Total population (million)	Urbanisation index (%)	Urban population (million)	Rural population (million)
96/97	934	26.9	251.38	682.82
01/02	1012	28.5	288.26	723.54
06/07	1092	30.4	332.23	760.17
11/12	1177	32.5	382.05	794.75
16/17	1264	34.7	438.05	825.95
21/22	1345	37.0	497.50	847.30
26/27	1414	39.5	558.36	855.54
31/32	1473	42.2	620.91	852.0
36/37	1527	45	686.93	839.58

Note: The population forecasts used by the Planning Commission are slightly higher in 2001/02 and 2006/07, but more or less similar in

2011/12. Information from the Household Consumption Expenditure Surveys, NSSO has been used for categorisation across income groups.

The average size of an urban household was 4.456 in 1994/95 while the average rural household size was 4.896 in the same year (Planning Commission report). The household size in the urban and rural areas are assumed to decrease to 4 and 4.5 respectively by 2036/37. Accordingly, the numbers of households in the urban and rural areas are estimated for the modelling period.

The households in the urban areas have been further split up into 3 income categories - viz. low, medium and high. These categories correspond to 1994/95 income levels in the range of Rs 75,000 and 150,000 per annum, Rs 150,000 and 300,000 per annum and incomes above Rs 300,000 per annum respectively[a]. Although rural population was also classified into 3 categories comprising low (incomes below Rs 25,000 per annum), middle (income between Rs 25,000 and 50,000 per annum) and high (income levels between Rs 50,000 and 75,000 per annum) income classes, the usage norms were applied to the total rural population due to lack of disaggregate data on penetration rates and usage of appliances.

The distribution of households by income category for 1994/95 in the urban and rural areas is based on the actual proportions as indicated by the Indian market Demographics Report (1996) of the NCAER. Over the 45- year modelling period, it is assumed that living standards would improve and the proportion of the high-income category would increase from 30% in 1994/95 to 40% in 2036/37 while the proportion of the low-income group decreases from 37% in 1994/95 to 30% by 2036/37.

Table 2 Distribution of households by income categories in rural & urban areas (millions)

	Urban			Rural		
	Low	Medium	High	Low	Medium	High
1996	20.8 (37%)	18.7 (33%)	17.2 (30%)	88.1 (63%)	35.0 (25%)	17.0 (12%)
2001	23.3 (35%)	22.1 (34%)	20.5 (31%)	87.6 (58%)	43.6 (29%)	18.7 (12%)

[a] Indian Market Demographics, I Natrajan 1996

2006	26.1 (34%)	26.5 (34%)	24.4 (32%)	87.0 (55%)	51.4 (32%)	20.6 (13%)
2011	29.2 (33%)	31.4 (35%)	28.9 (32%)	86.5 (52%)	58.7 (35%)	22.8 (14%)
2016	32.7 (31%)	36.9 (35%)	34.4 (32%)	86.0 (49%)	65.2 (37%)	25.2 (14%)
2021	36.6 (31%)	42.1 (35%)	40.9 (34%)	85.5 (47%)	69.5 (38%)	27.8 (15%)
2026	41.1 (30%)	46.4 (34%)	48.6 (36%)	85.0 (46%)	70.7 (38%)	30.6 (16%)
2031	46.0 (30%)	49.5 (32%)	57.8 (38%)	84.5 (45%)	69.2 (37%)	33.8 (18%)
2036	51.5 (30%)	51.5 (30%)	68.7 (40%)	84.0 (45%)	65.3 (35%)	37.3 (20%)

Note: Figures in brackets indicate percentage distribution of households

Gross Domestic Product (GDP)

The overall GDP data for the past 25 years (1970/71 to 1996/97) was taken from the National Accounts Statistics (NAS) compiled by the EPW foundation of India. Total GDP is further disaggregated into three broad sectors namely agriculture, industry and services.

Demand forecasts for the agriculture sector

There are two main energy end-use categories in the agriculture sector –land preparation and irrigation.

Land preparation

The energy demand for land preparation is estimated on the basis of the total gross cropped area that needs to be tilled.

The past data for gross cropped area (GCA) under major crops is taken from the CMIE document on Agriculture, 1999. The major crop categories included are rice, wheat, maize, pulses and sugarcane. Land area under each of these crops is aggregated to arrive at the total gross cropped area in the country.

Past trends have been used to extrapolate the area under each of the crops in the future. Accordingly, the GCA of different crops grows at different rates (based on past data) while the total gross cropped area grows at 0.71% per annum over the 40-year period. The demand for land preparation is provided as billion hectares of land to be tilled. The land preparation by tractor accounts for roughly about 75% of the total demand for land preparation. Table 5 gives the demand for land preparation in billion hectares.

Table 5 Demand for land preparation

Years	Billion hectares
1996/97	0.092
2001/02	0.095
2006/07	0.098
2011/12	0.101
2016/17	0.105
2021/22	0.109
2026/27	0.113
2031/32	0.117
2036/37	0.122

Irrigation

The energy demand for this end-use is estimated on the basis of the total water requirement by various crops in the country. Crop-wise data on the gross cropped area (million hectares) in the country was taken from the CMIE document on Agriculture. The net production of each crop was derived using average yields (kg/ha) for different crops after which average norms of water requirement (cu m /kg) for each crop were used to estimate the total water requirement for all the major crops. The proportion of area under crops irrigated by pumpsets was used to determine the demand for energy in this end-use sector. Table 6 provides the demand for water pumping in the agriculture sector in billion cubic meters of water required to be pumped.

Table 6 Demand for water pumping

Years	Billion cubic meters (b cu m)
1996/97	333
2001/02	407
2006/07	495
2011/12	598
2016/17	719

2021/22	1286
2026/27	1525
2031/32	1796
2036/37	2100

Forecasting of residential sector demands

Residential demands are estimated on the basis of user populations and estimated usage norms for each end-use category. The total urban population has been further split up into the low, medium and high income categories while the rural population is considered as a whole. The number of households in each of these categories have been determined as explained in the section on energy drivers. The main end-use categories in the residential sector are lighting, cooking, space-conditioning, water heating, refrigeration and use of other electrical appliances.

Energy demands for space conditioning, water heating and refrigeration are based on usage norms and penetration rates as discussed below.
Table 8 gives the penetration rates (number per 1000 households) of the various appliances across different income categories. The energy demand is estimated as the product of the penetration rates and the usage norms.

Table 8 Penetration rates of various appliances (nos./000 hhs)

End use	Rural		ULIG		UMIG		UHIG	
	1996	2036	1996	2036	1996	2036	1996	2036
Fans	323	420	430	1180	1191	1721	1727	2000
Water heating	0.8	4.1	4.4	70.6	72.7	237	237	260
Refrigeration	20.6	29.8	31.6	316.7	321.6	600	600	650
Coolers	0	0	0	0	629	1717	0	0
AC	0	0	0	0	0	0	575	2290

Residential demand for lighting

The demand for lighting is estimated separately for the rural population and for the low, middle and high-income categories among urban households. The norms for lighting demand per household in each of the categories is estimated based on the following assumptions:

- Rural households: 33% of the rural households are assumed to use hurricane lanterns, 33% assumed to use petromax lanterns and the rest use a bulb for 4 hours a day.

- Low-income urban households: A typical household in this category is assumed to use one 60W bulb for 7 hours/day and two 25W bulbs for 2 hours/day.
- Middle-income urban households: A typical household in this category uses an average of the consumption in the in the low-income and high-income households.
- High-income urban households - A typical household in this category is assumed to use one fluorescent tube light for 5 hours/day, two 60W bulbs for 7 hours/day, and one 25W bulb for 2 hours/day.

The resultant norms for lighting demand in each of the categories are indicated in Table 10.

Table 10

Category	Lumen hours / annum
Rural households	988907
Urban low income household	2014800
Urban middle income household	5422075
Urban high income household	8829350

The total demand for lighting is then worked out as the product of the usage norm and the number of households in each of the categories. The total lighting demand is provided in Table 11.

Table 11 Lighting demands (Tera lumen hours / annum)

Years	Urban	Rural	Total
1995	287	137	424
1996	296	138	434
2001	348	148	496
2006	411	157	568
2011	485	166	651
2016	570	174	744
2021	663	181	844
2026	764	184	948
2031	871	185	1057
2036	990	188	1177

Demand for cooking in the residential sector

Energy demand for cooking in the residential sector is based on the estimates of per capita useful energy requirement in the rural and urban categories. The model considers a norm of 500 Kcal/ capita in the urban sector and 400 Kcal/capita in the rural sector for cooking purposes only. Useful energy requirement for cooking estimated as the product of the useful per capita energy requirement and the respective population in the rural and urban areas is shown in Table 12.

Table 12 Energy Demand for cooking in residential sector

Years	Urban (PJ)	Rural (PJ)	Total (PJ)
1996/97	192.2	417.7	610.0
2001/02	220.4	442.6	663.0
2006/07	283.5	465.0	748.5
2011/12	292.1	486.2	778.3
2016/17	335.0	505.3	840.2
2021/22	381.4	518.3	900.0
2026/27	427.0	523.4	950.3
2031/32	474.8	521.2	996.0
2036/37	525.3	513.6	1038.9

Kerosene demand in the commercial & residential sectors

Time series data for consumption of kerosene was available in the aggregate form for the residential and commercial sector. The forecast for kerosene has therefore been carried out as a whole and this would need to be segregated among the residential and commercial sectors for the model input. Table 13 provides the estimates for the total kerosene demand in the 2 sectors.

Table 13 Total kerosene demand ('000 tons)

Years	Scenario 1 (6% GDP growth)	Scenario 2 (6.5% GDP growth)
96/97	9878	9878
01/02	13487	13614
06/07	18479	19094
11/12	25317	26781
16/17	34687	36692
21/22	45334	50272
26/27	59250	68876
31/32	77437	92172
36/37	101208	123347

On the basis of the above assumptions, data and estimations, the following results were derived.

MARKAL Output

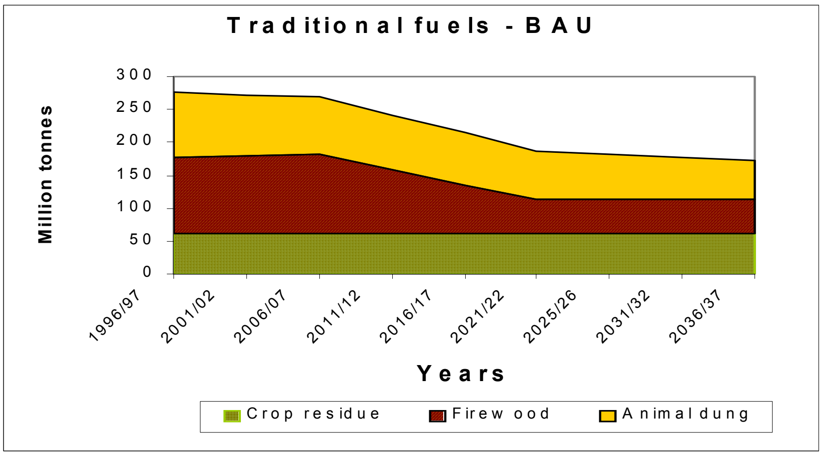
Traditional fuels

Table Traditional fuels (MT)

		1996/97	2001/02	2006/07	2011/12
		Markal	Markal	Markal	Markal
Supply	**(A+B-C)**				
A. Production		**276.14**	**271.60**	**269.94**	**242.00**
	Firewood	115.84	116.21	119.45	96.41
	CR	62.26	62.26	62.26	62.26
	Dung	98.04	93.14	88.24	83.34
Consumption		**276.14**	**271.60**	**269.94**	**242.00**
FW	**Domestic**	74.72	83.63	91.61	81.34
	Commercial	41.13	32.58	27.84	15.07

CR	**Domestic**	61.47	60.89	60.28	59.74
	Power	0.78	1.37	1.97	2.51
Dung	**Domestic**	98.0	93.1	88.2	83.3

Traditional Fuels:BAU



Oil Demand: Agriculture and Residential Sectors only

Table Oil Demand projections Oil (MT)

			1996/97	1999/00	2001/02	2006/07	2011/12
		Actual	Markal	Actual	Markal	Markal	Markal
Supply	**(A+B-C)**	**82.72**	**85.93**	**100.06**	**162.56**	**231.93**	**234.05**
A. Production		32.90	32.90	31.90	35.02	37.14	39.26
B. Imports		**52.98**	**57.77**		**104.46**	**137.99**	**220.68**
C. Exports		**3.16**	**4.74**	0.93	**10.65**	**10.45**	**25.90**
Consumption		**64.41**	**64.8**		**80.0**	**108.0**	**150.1**
Agriculture	Diesel	0.62	1.74		2.68	3.62	4.56
Domestic	LPG	3.35	7.95		9.79	11.76	14.24
	Kerosene	8.1	9.90		0.03	0.00	0.00

Power Demand: Agriculture and Residential Sectors only

Power demand projections {Power (TWh)}

		1996/97	2000/01	2001/02	2006/07	2011/12
	Actual	Markal	Actual	Markal	Markal	Markal
I. Generation (A+B+C+D+E)	**436.65**	**444.07**	**543.00**	**535.56**	**663.58**	**849.03**

			1996/97	2000/01	2001/02	2006/07	2011/12
		Actual	Markal	Actual	Markal	Markal	Markal
A. Thermal		317.03	327.94	408.00	360.92	417.67	534.18
	Coal	289.37	301.11		325.01	366.35	428.25
	Diesel	0.68	0.00		0.00	0.00	0.00
	Gas	26.98	26.83		35.91	51.32	105.94
B. Hydro		68.90	69.25	74.00	92.00	131.61	171.22
C. Nuclear		9.07	8.13	17.00	8.13	9.29	10.45
D. Wind		0.88	0.54		0.93	1.31	1.69
E. Captive		**40.78**	**38.75**	**44.00**	**74.51**	**105.01**	**133.18**
	Coal	29.12	27.86		50.86	74.09	99.20
	Diesel	6.62	4.18		8.07	9.80	11.69
	Biogas		2.42		3.72	4.97	6.16
	Gas	5.04	4.30		11.86	16.15	16.14
II. Generation excluding captive		**395.87**	**405.32**	**499.00**	**461.04**	**558.57**	**715.85**
III. Consumption		**280.18**	**280.04**		**326.36**	**407.28**	**533.09**
	Agriculture	84.01	84.54		97.85	114.39	134.46
	Domestic	55.26	56.28		66.90	81.47	103.88
IV. T& D Losses	Excluding captive	**29.22**	**30.91**		**29.21**	**27.09**	**25.53**

Other projections:
Apart from the MARKAL projections, given below are the biomass demand figures estimated by the Planning Commission, Power and Energy Division, July 2000, in its draft Energy Policy Committee Report.
The figures pertain to three scenarios-

(a) Frozen Efficiency Scenario (FE): where the efficiency in energy use in different sectors of consumption continues to remain at the same level as in the base year 1994-95
(b) Business-as-usual Scenario(BAU): where the efficiency of energy used is assumed to increase at the rate of 0.5% to 1% per annum.

Energy Demand Projections

Non-Commercial Energy

Source	**Scenario**	**2001-02**	**2006-07**	**2011-12**
Fuelwood	FE	165.64	215.34	235.72
(Million Tonnes)	BAU	181.94	182.64	180.83
	EFF	160.19	131.53	118.18
Dung Cake	FE	103.88	112.24	120.78
(Million Tonnes)	BAU	100.69	100.87	101.87
	EFF	92.27	79.94	75021
Crop Waste	FE	60.77	66.78	72097
(Million Tonnes)	BAU	60.02	64.24	69013
	EFF	50.61	42.03	40.46
BioGas	FE	1537	1902	2273
(Million Cubic Meters)	BAU	1537	1902	2273
	EFF	1464	1665	1911

(c) Efficiency Scenario (EF): where changes in efficiency improvements in energy production and utilization in addition to improvements that may be achieved in the BAU scenario is assumed in order to realize the full potential for energy saving and inter-fuel substitution possibilities.

In the wake of the above results from MARKAL which give the macro level optimum values of energy demand from which the rural sector has to be segregated, the by I. Natarajan forecasts demand for the biofuel in rural Indian households.

The paper by Natarajan focuses exclusively on the biomass energy consumption of the rural households and projects the future demands for the same. However, this paper captures only rural biofuel consumption for heating purpose only and excludes the use of any commercial fuel or energy consumption for any other purposes.

In predicting the future biofuel demand, Natarajan uses the data on energy use and the pattern of fuel consumption collected from sample households available from the "Evaluation of NPIC" studies, conducted by NCAER for the years 1992-93 and 1996-97. Keeping the baseline survey of 1978-79 of NCAER at the backdrop, the paper attempts to estimate the biofuel demand in rural India by the end of the Ninth and Tenth Five Year Plans of India.

The table below gives a synopsis of the projected demand for biofuels , though they cannot be pitted against the MARKAL output since the latter gives cost minimized values only.

Projected demand for heating energy and likely pattern of fuel use in rural households, 2001-2 and 2006-7

		2001-2			2006-7		
Fuel	Unit	Qty	ktcr	share	Qty	ktcr	Share
Coal/ Soft coke	10^3 t	420	572	0.3%	420	572	0.2%
Kerosene	10^3 kl	1,559	9,666	4.8%	1,901	11,786	4.8%
Dung cake	10^3 t	103,093	31,959	15.8%	113,481	35,179	14.3%
Firewood: logs	10^3 t	74,714	70,979	35.0%	94,760	90,022	36.5%
Firewood: twigs	10^3 t	95,091	58,006	28.6%	120,604	73,568	29.8%
Crop wastes	10^3 t	39,102	23,852	11.8%	41,615	25,385	10.3%
Biogas	10^6 m^3	1,108	3,878	1.9%	1,521	5,324	2.2%
Others	--		4,059	2.0%		4,935	2.0%
Total	**--**		**202,970**	**100%**		**246,771**	**100%**

Source:Natarajan.I, Demand Forecast for Biofuels in Rural Households.

Some other models

Outside the boundaries of TERI, there exists the **INGRAM Energy Model** envisaged by Jyoti Parikh, R.Ramanathan and J.P.Painuly. Given the fact that rural India is heavily dependent on biomass-based energy sources, this model focuses on the policy questions regarding the fuel-fodder-fertilizer relationships for biomass utilization in rural areas of developing countries like India, the impact of price change on commercial fuels on the biomass sources, role of livestocks in this context, the implications of reduced biomass availability in the wake of increasing population pressure and finally the changes in fuel-fodder-fertilizer relationships when environmental considerations like pollutant emissions, soil erosions are also considered.

This linear programming model developed by Jyoti Parikh (1985) investigates the energy- agriculture linkages. Bangladesh (Parikh & Kromer 1985) was the first country where this model was applied before it was tried on India in the states of Punjab (Panesar et al, 1992), Uttar Pradesh (Singh et al, 1992) and Karnataka (Painuly et al, 1995) to assess the impacts of alternative policies.

The model maximizes the revenue available from crops and milk, subtracting the expenditure of buying feeds, fuels and fertilizers. The biomass demands for cooking are considered in competition with demands for feed and organic fertilizers. The constraints constitute of: the crop residue balance, feed balance, dung balance, fertilizer nutrient balance, cooking energy balance and energy supply constraints for individual fuels.

The environmental criteria viz. the environmental emissions, which are typically proportional to the fuels used for cooking; and the soil fertility loss due to dung burning, are incorporated later, after the model solves for revenue maximization.

Thus, at the end, the model solves for three objectives- net revenue maximization and minimization of two environmental goals. Simultaneous consideration of three objective functions indicates a multi-objective analysis based on which the goal programming (GP) version of the same LP model has been developed.

Validation of the model for 1990-91

The base year for the model is 1990-91 and the model-results of the base year are validated with the actual figures, so as to assess the viability of the model outputs. Due to uncertainties in data, a number of variations are made to test the model and check for its consistency.

Comparison with actual data indicates the following:

(a) The total inorganic fertilizers use indicated by the model is 44.03 tons of nitrogen, 17.63 tons of phosphorous and 7.16 tons of potassium per hectare of GCA as against the actual values of 44.4, 17.88 and 7.37(FAI, 1992) respectively.

(b) Data for dung production could not be traced from any reliable source(s), but the model figures of 3.7 kg of dung per bovine per day are in lines with the figures prescribed in Painuly (1992; 1995), Singh et al (1992), Safely et al (1992) and Stout (1990).

(c) The actual figures for kerosene consumption for cooking purposes in rural India during 1990-91 was not collected and it has been estimated as a certain percentage of the total kerosene consumption in Indian households equal to 10800 litres (CMIE, 1992b). The model estimates a consumption of 1261 litres of kerosene for cooking purpose in the rural households, approximately equal to 11.68% of total kerosene consumption which compares well with the share (9.5%) of cooking estimated by Natarajan (1985) for the year 1978.

Thus the model results are pretty close to the original data, indicating the validity of the model structure and the values of the parameters. Alternative scenarios are also incorporated in the model to make room for alternative policies.

The Planning Commission of India used the **MEEDE-S** approach in 1991 to estimate the energy demand in India till the year 2009. The MEEDE-S approach provides a quantitative analytical framework to estimate energy demand in the long run since the conventional econometric techniques are fairly consistent in the short run and medium run, but not in the long run. The end-use demand driven model permits analysis with reference to technological options and fuel-mix choices while allowing for structural changes in the economy.

Besides the macroeconomic assumptions of 6% growth in GDP during the 1987-2009 and population touching the 1140 million mark by the year 2009, the rural component of the model assumes large scale energization of pump sets by the year 2009 in the agricultural sector, while changes in the pattern of income distribution along with its repercussions on the standard of living and consumption of fuel are also incorporated in the model. Emphasis on rural electrification is reflected in the base case scenario, by taking into account the increasing demand for electricity from rural households for lighting purpose along with the implications of substituting traditional fuels by the commercial ones on the demand for kerosene and LPG.

The Planning Commission report based on the MEEDE-S exercise mentions the need to estimate the energy requirements with reference to different agro-climatic regions, especially to obtain data on the extent to which diesel and electric pump sets as well as tractors are utilized in the different regions. The report also touches upon the fact that numerous studies carried out on energy consumption in the household sector are not comparable. It also stresses on the necessity to carry out periodical surveys (every three to five years) on the patterns of energy consumption with reference to fuel mix, income variation, urban/rural differences and the end use efficiencies of different types of domestic appliances, so as to analyse accurately. The report also identifies the lacuna of not including decentralized energy systems based on renewable sources along with the drawback of not incorporating structural changes in the economy that could lead to drastic changes in the overall energy efficiencies.

Along side the optimisation models sketched above, there is an energy accounting model like the **Long-range Energy Alternatives Planning Model (LEAP)** which stands out as a simulation model used to represent the current energy scenario for a given area and to develop forecasts for the future under certain assumptions.

This end-use, demand driven model consists of five modules comprising of demand, transformation, biomass, environment and evaluation. There is provision for an explicit inclusion of biomass as a source of energy in this model. The evaluation of the biomass resources is incorporated through land use evaluation where the study area is divided in a tree structure of sub areas, zones and land use types. For all land use types, the acreage, productivity and the access fraction is mentioned. The last factor accounts for the maximum amount of annual yields and stocks that can be used for energy purpose taking into account the limiting elements like the distance, land tenure and the harvesting constraints.

The figure below explains the nature of disaggregation for biomass resources. In this example, two areas- north and central have been considered, each comprising of two zones-forest and non-forest, each with the type of land use. The percentages specified indicate the share of the resource on that type of land that is available for energy use.

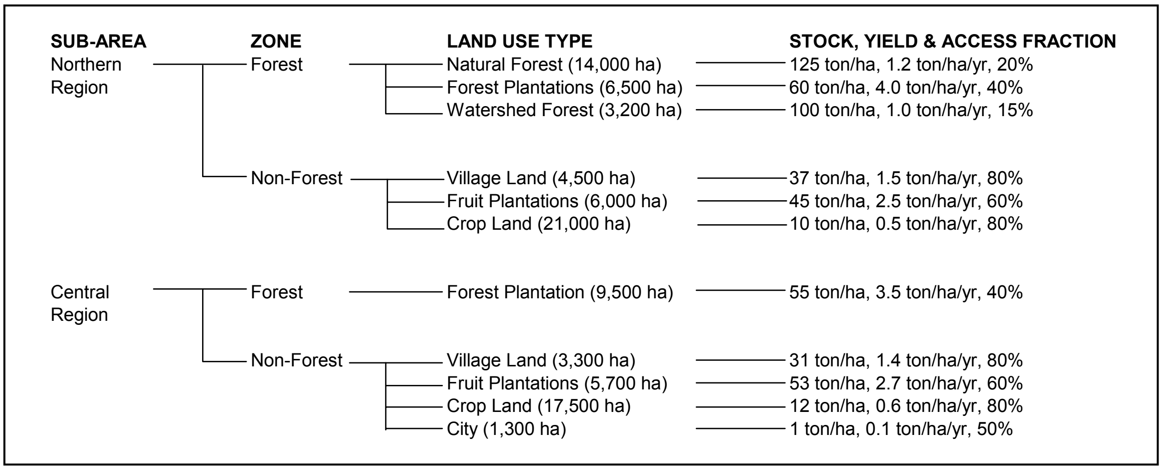


Figure 1. Example of a wood resource structure in the biomass model of LEAP
Source: (Joost Siteur, RWEDP, LEAP and Wood Energy Planning)

The crop residues and animal dung are also calculated on a sub-area basis, to allow for the evaluation of the supply of these biomass fuels. The figure below sketches the fuel flow in the LEAP Model.

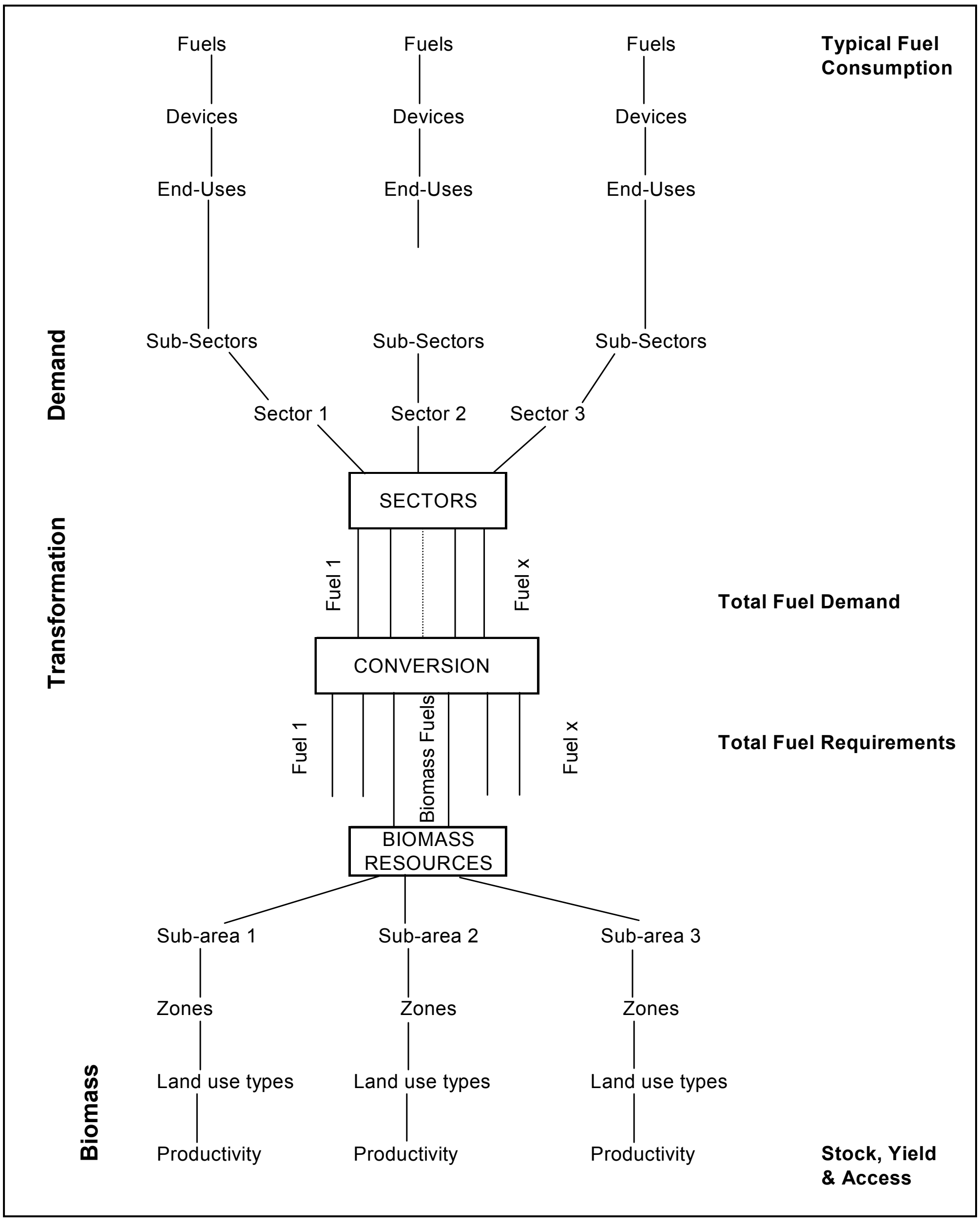


Figure 2 Overview of the demand, transformation and biomass modules of LEAP
Source: (Joost Siteur, RWEDP, LEAP and Wood Energy Planning)

The model contains an Environmental Database (EDB) which contains data on the environmental impacts on water, soil and air for the different types of end use and transformation devices. This gives an insight into the impacts of changes in demands or device type.

Apart from the base case scenario, other alternative scenarios can be developed by changing the values of one or more factors. The last bit of the model allows the evaluation of the alternative scenarios pitted against one another or the base case. This directs the modeller towards an optimised and feasible solution.

The preceding description of the model throws a hint on the fact that this can be used for biomass energy planning. The model provides a comprehensive framework for the whole energy flow from the biomass sources through conversion to the end use consumption. And since biomass still remains the lifeline of energy in the rural sectors, in the process, the model takes care of rural energy planning as well.
(Source: Joost Siteur, RWEDP, LEAP and Wood Energy Planning)

Though the scope of the model includes a wide spectrum ranging from integrated energy planning at the national and regional levels to possibilities of energy conservation, GHG emission possibilities to global energy and climate change studies, it can very well focus on rural energy planning as pioneered by RWEDP and FAO of the UN in collaboration with Stockholm Environment Institute (SEI), who have adopted LEAP as a tool for organizing and analysing biomass and rural energy issues. (Source: SEI website)

Energy Models: what do we achieve?

A glimpse at the above mentioned models throws light on the fact that one stock model is not the answer for an economy wide planning exercise. This becomes all the more relevant in the Indian context since the country is a mosaic of varying climatic and socio-economic zones. This kind of heterogeneity does not get reflected in the macro models like TEESE or MARKAL, as they treat the entire economy as one single unit.

Heterogeneity also exists at the smallest level of the economy, viz. the villages. There are villages where it is easier to implement energy related policies due to the conducive location or climate or the residents' favourable responses in adopting changes due to reasonable purchasing power and advanced mindsets. All these factors become important in the wake of rural energy planning apart from the normal energy demand/supply considerations. It is imperative to include such micro considerations in the models since output might very well indicate that optimal energy supply requires n units of electricity to be provided to the villages, while reality might be that it is technologically infeasible to connect certain villages to the grid due to their remote positions. Thus one should not only get a clue as to how much energy should be supplied to meet a certain amount of demand, but should also be able to get a solution as to how exactly this demand should be met.

Typically all these models answer the question of how much energy should be provided but not on how they are to be provided. For that one needs to go down to the village level and work things out in accordance to what suits the particular village in question.

Even if one accepts that models can take care of such factors, then the next question arises as regards to the time of planning and its subsequent implementation. There exists a considerable time lag in data collection, compilation, its incorporation in the model, obtaining the optimal solution and finally its implementation. So we might very well face a situation where at the time of implementation of the planned programs, ground realities have changed to a large extent with its repercussions on energy forecasts. Its not very clear whether the models discussed incorporate this revision in data forecast/information arising due to time lag.

One again comes back to the question of the treatment of the regional differences in the model. The calculation of rural energy demand for cultivation and the domestic sector are based on the norms of energy consumption standardized at the national level. This does not account for regional disparities in consumption norms and hence the resultant demand calculations are also generalized.

Even when planning is done specifically for the rural sector, there arises one source of discrepancy. The supply of fuelwood, which is regarded as the lifeline in the developing countries, is calculated on the basis of area under forestry, while the actual usage is in terms of logs or branches. Hence there is a difference in units in the fuelwood demand and supply figures.

Way ahead and future research scope:[a]

Future research scope lies in developing models which would dwell on the objective of capturing the rural energy transition. This would be distinct from the above mentioned models whose objective functions are either energy cost minimization or maximization of revenues of the farmers.

This would require identifying the nature of transition, developing indicators to capture the same, collecting relevant data and finally incorporating the underlying assumptions and data in the concerned model. The key rural energy transitions consist of:

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[a] I am grateful to my colleague Vikram Dayal for his comments which helped in shaping up this particular sub-section.

- Movements of households up or down the domestic energy ladder and the associated huge improvements or deterioration in the indoor air environment.
- The shift from animal power to tractors and pumpsets for ploughing and irrigation respectively
- The shift of dependence from public or common land to private land and the associated change in property rights regimes
- The change in attitude towards "policy makers" from what may crudely be termed top-down to bottom up, from keeping people out to involving them, to handing out energy efficient devices to designing processes whereby people choose to adopt energy devices that improve their well-being.

These transitions are nested within larger transitions in the rural landscape, notably demographic change, both of the increase in numbers and urbanisation; technological change and agricultural development, etc.

One issue that is particularly significant in rural energy transitions is scale dependence: two villages close by may have very different profiles and local and state transtions could possibly be different. Another issue is the possibly different fortunes of different socio-economic groups.

Arguably, such macro models as TEESE and MARKAL simply haven't attempted to answer questions of rural energy transitions. They have looked at the national energy scene and take as given certain parameters.

What could a future modelling strategy for rural energy transitions be?
It would have to build from the numerous field and micro studies, and investigate and explore different ideas of rural energy transitions. Perhaps some simulation modelling done at different time and spatial scales along with studies to test and improve key relationships is the way to go. These simulations would be based on relationships between household choices, energy stocks and drivers.

At the end of it, what one can say is that modelling is only a tool or an instrument. It is not a magic wand that can define a perfect path for the economy or any of its component sectors. One can only get a clue or guidance from them since such models are not “ prescriptive” but rather “ directive” in nature. So, while staunch supporters of market economies denounce the idea of planning including energy planning, in the words of Amulya Reddy one can defend the entire planning exercise as a means to achieve an end, the end being development.

Infact, with the Tenth Five Year Plan (2002-2007) shifting its focus from industry-oriented growth to agriculture-led growth (Pant, The Statesman, New

Delhi, 19.09.2002), the importance and the urgency to include the rural sector in planning models becomes all the more imperative.

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