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Decision support system for regional domestic energy planning

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Rural energy planning depends solely on the existing levels of energy consumption in domestic sector. In India, energy requirements for cooking and water heating depend predominantly on biomass fuels, which are often burnt in traditional stoves (efficiency < 10%), while kerosene and electricity are used for lighting. A sound environmental development of a region needs promotion of conservation activities among local communities and application of traditional environmentally sound technologies. Environmental research activities in recent years have generated large data on energy processes, mainly on commercial sources of energy such as, coal, oil, natural gas, and electricity are generally available, a lot of effort is still required to quantify traditional sources of energy. In this regard, Decision Support System (DSS) with relevant data help the decision makers to take appropriate timelier decisions and assist in the evaluation of reliability and the generation of alternatives. DSS incorporates simulation and optimization models with interactive graphics capabilities to encourage the acceptance of analyzing techniques in practice. This paper presents a conceptual framework for analyzing energy consumption at domestic sector via DSS. The framework is based on material flux, comparative analyses of village level domestic energy consumption patterns across various zones considering regional and seasonal variations. It also differentiates between household activities like cooking, water heating, and space heating which are the major end use activities. The system with a synergistic integration of software tools will assist decision makers in understanding the process status better and also aid in providing timelier decisions and efficient outputs. DSS is validated with the data pertaining to energy situation of Kolar district. Stratified random survey covering 2500 households distributed uniformly over the district shows that most households still use traditional stoves for cooking (97.9%) and water heating (98.3%). Energy analysis shows that the consumption ranges as follows: fuel wood for cooking, 0.69±0.34-1.42±0.27 kg/capita/d; electricity for lighting, 5.17±2.16-6.57±4.07 kWh/capita/month; kerosene for cooking, 0.44 ±0.16-1±0.76 l/capita/month; LPG for cooking, 0.18 ±0.05-1.03 ±1.35 kg/capita/month; and, biogas for lighting, 0.6 ±0.29-0.76 ±0.28 m^3/capita/d.

Keywords: Energy, DSS, Fuel wood, Sustainable development, Regional planning

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Introduction

Sustainable development of a region depends critically on the health of renewable resources such as, soil, water, vegetation, livestock, and genetic diversity. The integrated development of all these components is essential for environmentally sound development. This necessitates promotion of conservation activities among local communities and application of traditional environmentally sound technologies[1]. This can be achieved by adopting holistic approach in energy planning, the main objective of which is to find solutions to match demand and supply of energy sources[2]. Now the focus of energy sector planning is shifted from supply to energy demand analysis, demand management and conservation with a good understanding of the factors affecting the growth and pattern of energy demand before arriving at demand projections. Demand analysis involves assembling and presenting a consistent set of data on consumption and demand for various forms of energy (fuel wood, electricity, kerosene & LPG). It also involves the estimation of level of shortage or unfulfilled demand; and quantifying the relationship of demand with relevant economic and non-economic variables such as, income, population and prices of different energy sources, and their substitutes. Analysis of energy from various sources and demand (sectoral analysis) for various fuels can be made efficiently with Decision Support System (DSS). In addition the scenarios for the future take into account the changing relationships between economic growth, energy consumption, and the potential for fuel substitution. Thus,

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DSS assists in strategic decision-making activities, which help in regional energy planning of renewable sources and conservation.

Energy Demand Analysis

Energy demand analysis is the first step towards determining whether it is feasible to put together an energy supply mixes compatible with the achievement of a sustainable world at the projected energy demand levels[3]. It considers the activities in individual energy-consuming sectors of the economy. It relates macro-economic developments to the energy needed to support those developments in each sector. Demand analysis enables a disaggregated, end use approach to analyze the energy requirements. It uses economic, demographic and energy use information to compute and report on total and disaggregated consumption of various end use fuels[4]. It plays a sequential, intermediate, and iterative role in energy planning. First, it follows the phase of database establishment. Secondly, its output serves as input to energy policy analysis. Finally, demand analysis occurs iteratively. Two major approaches of energy demand analysis are macro and sectoral demand analysis. Macro demand analysis considers demand as a function of population, income, and prices. Sectoral demand analysis examines the structure of sectors and sub-sectors and their energy consuming activities, including the equipment[2]. The issues associated with energy demand analysis are:

- Most energy planning exercises are carried out with aggregate data at national level. At regional level, there have been fewer efforts for energy planning. Energy resources and demand are spatially distributed[5].
- Studies of traditional fuel sources are needed to focus on issues such as, changes in supply and demand of biomass fuels, determinants of use of biomass sources as fuel, fodder and fertilizer, changes in efficiencies of conversion and utilization, processes of generation and use of traditional sources of energy in the context of socio-political characteristics of a location.
- Meeting the basic energy needs of population at a reasonable cost would be an important policy objective, it is therefore necessary to identify regions and households that currently face deficit or likely to develop a deficit in biomass resources and to analyze how their current needs are being met.
- There is a need to review the method and collate the results of available studies on energy demand analysis and management. Such a review should collate empirical information on the role of energy prices, possibilities of interfuel and interfactor substitution, and economics of conservation.
- Analysis of various methods of estimating energy shortages or unfulfilled demand for different sectors and categories of consumers.
- Estimates should be made of energy shortages and the processes through which the shortages have been managed. The impact of shortages on agricultural output, industrial output, employment, regional development, income distributions, consumer welfare, consumer health, etc., should be quantified.
- In the context of energy demand, there is a need to evaluate the social profitability of the allocation of various scarce resources to conserve rather than augment[6].

Energy Consuming Sectors

Sectors for energy analysis can be categorized as: i) Domestic sector (lighting, cooking, heating and other uses); ii) Municipal sector (street lighting, public water works); iii) Industrial sector (process heating, electric drive ore reduction, and industrial lighting); and iv) Transport sector; and, Agriculture sector (irrigation, harvesting, thrashing and land preparation). These sectors represent a mixture of different types of rural and urban households, industries, agriculture, and other establishments, which are often difficult to disaggregate with any reasonable degree of confidence. The largest single component of demand in this group stems from households.

The consumption of energy for lighting, cooking, heating, and other appliances by households and the service industry has shown significant changes in the recent past. Growth in household incomes and in urbanization has been accompanied by a change in the fuel mix to more efficient fuels; partly as a result, energy consumption per household appears to have stagnated in some countries. While an urban home largely depends on cooking gas and electricity for its energy requirements, 85 - 90 per cent of the energy demand of a rural home is dependent on firewood or fuel wood[5]. The domestic energy expenditure, with the increasing cost of energy, is gradually assuming a sizable share of the total domestic expenditure.

Energy consumption patterns in the Indian residential sector vary widely not only among the rural and urban areas but also across various income classes in urban areas. In India, approx 86.1 per cent rural households use fuel wood and dung cakes for cooking, while 3.5 per cent use LPG for cooking. For lighting, 50.6 per cent of rural households use kerosene and 49.4 per cent uses electricity. Out of annual average consumption of fuel wood (270 - 300 mt) and kerosene (10.5 mt), 60 per cent was in rural areas[7]. The levels and forms of fuel consumed by the household sector depend on income levels, size of settlements, households and city, price of fuels, the availability and accessibility of modern commercial fuels, and the efficiency of the end-use equipment used. Differences in energy-use lie both in terms of per capita energy consumption and in choice of fuel to meet the energy demands. It has been observed that with higher levels of development in the economy and rising per capita income, households tend to move towards fuels that are cleaner, more efficient, convenient, and more expensive.

Energy Supply Analysis

Energy supply analysis normally incorporates the information on the present energy supply system and the potential for the future. This includes the assessment of energy sources and the evaluation of the fuel distribution and supply technologies. Technology evaluation provides information on technologies used for the processing of raw energy into energy forms that are useful to end users, while resource assessment provides the quality and cost of energy sources. The work has been done in this regard, to assess bioenergy potential for a region (Kolar district) using Bioenergy Potential Assessment (BEPA), a spatial decision support system. The main hypothesis is that, this tool can be used to form a core of practical methodology that will result in more resilient in less time and can be used by decision-making bodies to assess the impacts of various scenarios and to review cost and benefits of decisions to be made. It also offers means of entering, accessing, and interpreting the information for the purpose of sound decision-making.

The bioresource assessment requires estimation of the available bioresources and demand spatially for evolving better management strategies to ensure sustainability of resources. In this regard, Geographical Information System (GIS) plays an important role in providing geographically referenced spatial distribution of potential and demand on temporal scale. It offer tools for handling and analyzing socio-economic problems in addition to spatial analyses, particularly those related to decentralization and distribution of service and facilities, which helps in formulating policies. The ability of GIS is to integrate spatial data from disparate sources with different formats, structures, projections, or levels of resolutions[8].

The DSS is built in a GIS environment with the objective to exploit its powerful features in handling all the parameters with geographic variability that influence biomass availability, site selection of the energy conversion facility and estimation of the performance and cost of the energy produced. The spatial distribution of renewable energy sources potential, the inherent renewable energy sources dependence in site specific characteristics and the overall cost dependence on spatial attributes make GIS an indispensable tool for energy management. The DSS, which incorporates the advantages, offered by GIS technology in order to fully exploit renewable energy sources databases and handle efficiently the geographic characteristics that affect renewable energy sources potential and energy cost.

DSS has already been used to analyze village level domestic energy consumption patterns[5], in a power plant simulation tool[9], for energy planning in Bankura district[10] and energy demand model for transport, industrial and residential sectors in Thailand based on LEAP (Long-Range Energy Alternative Planning)[11].

Objectives

The main objective is to design and implement a Spatial Decision Support System (SDSS), which is capable of performing the following activities: (i) Determine the fuel consumption pattern in various agro-climatic zones and determine the parameters involved in the variation and level of consumption; (ii) Measure and estimate the daily per capita fuel wood consumption in traditional and improved stoves for cooking, water heating, etc; (iii) Providing means of entering, accessing and generating reports (based on indices of consumption); and (iv) Analyses of energy indices and interpretation for the purpose of sound decision making.

Thus the overall objective of this DSS is the development of set of tools aimed at transforming data into information and aid decisions for domestic energy consumption.

Technical Description

The DSS provides and integrate framework for easy access of data analysis and the design and evaluation of domestic energy consumption strategies with a unified user interface (Fig. 1), comprising: i) Fully menu-driven Graphical User Interface (GUI), with a built in context sensitive help features; ii) A special feature of the database is its handling, display and analysis of observation time series data, with a linkage to real time data acquisition and monitoring; iii) Comparative analyses of State to village level domestic energy consumption patterns; and iv) It supports realistic analysis and practical simulations of energy consumptions.

Methodology

DSS of domestic energy demand assessment (Fig. 1) is developed with a GUI, using Microsoft Visual Basic 6.0 (VB 6.0) as front-end and Microsoft Access database as backend. GUI environment helps in entry, update of database along with options to compute domestic energy consumption at selected locations. Integration of this module in GRAM++ (GIS software) helps in spatial and temporal analyses[12].

Case Study and Implementation of DSS

Sector-wise disaggregated information of energy usage is developed for the district to assist in regional energy planning exercise. This case study provides comparative analyses of village level domestic energy consumption pattern considering regional and seasonal variations. Cooking, water heating, and space heating are the major end use activities. Results based on 18 months of field research in all taluks of Kolar district reveal that the average energy consumption norm does vary significantly for cooking and water heating in various seasons across the district.

Study Area

Kolar district is located in the southern plains of Karnataka State, India (Fig. 2). It lies between 77° 21' to 78° 35' east longitude and 12° 46' to 13° 58' north latitude and extends over an area of 8,225 sq. km. The population was 2.52 million in 2001. For administrative purposes, district has been divided into 11 taluks. There are 15 towns and 3,345 inhabited villages in district Kolar belonging to semi-arid zone of Karnataka. In the semi arid zone apart from the year-to-year fluctuations in the total seasonal rainfall, there are also large variations in the time of commencement of rainfall adequate for sowing as well as in the distribution of drought periods within the crop-growing season. Kolar district depends on rainfall during southwest and northeast monsoon. Out of about 2,80,000 ha of land under cultivation, 35 per cent is under well and tank irrigations. There are about 951 big tanks and 2934 small tanks in the district.

Average population density of the district is 2.09 persons/ha (rural) and 2.69 persons/ha (rural + urban). The population density ranges from 1.44 (Bagepalli), 1.69 (Gudibanda), 1.70 (Srinivasapur) to the maximum of 2.55 (Kolar). While population density in taluks lies within this range - Bangarpet (2.52), Malur (2.38), Gauribidanur (2.36), Sidlaghatta (2.16), Chintamani (2.10), Mulbagal (2.04), Chikballapur (1.92).

Average livestock density of the district is 0.81. It ranges from 0.68 (Bagepalli, Malur), 0.70 (Kolar) to a maximum of 1.09 (Gauribidanur). Extent of forest cover in the district is about 6.5 per cent (Bangarpet, 1.71; Malur, 2.3; Kolar, 2.78; Srinivasapur, 15; and Chikballapur, 20 %). Taluks are grouped into three groups (<10 %, 10-20 %, and >20 %) based on percentage of forest cover. Chikballapur and Bagepalli have forest cover > 20 per cent, Gudibanda and Srinivasapur are in the range 10 - 20 per cent, while remaining taluks have forest cover < 10 per cent.

In order to get an insight into the energy consumption pattern and extent of variation in the domestic sector, detailed energy surveys were conducted in the district, consisting mainly of secondary and primary data collection. An exploratory survey was conducted in various taluks initially. Stratified random surveys of fuel consumption were conducted in 2500 households from 137 villages uniformly distributed over all taluks of Kolar district to assess the energy situation in the district. Data collected from these houses were computerized and verified (survey was repeated in households to ensure the data consistency). Removal of ambiguous and inconsistent data is about 17 per cent and the final analyses were carried out for the consistent data of 2080 households (83 %). Per capita fuel consumption is computed season-wise and region-wise to determine the fuel consumption pattern and its variability considering the seasonal and geographical factors.

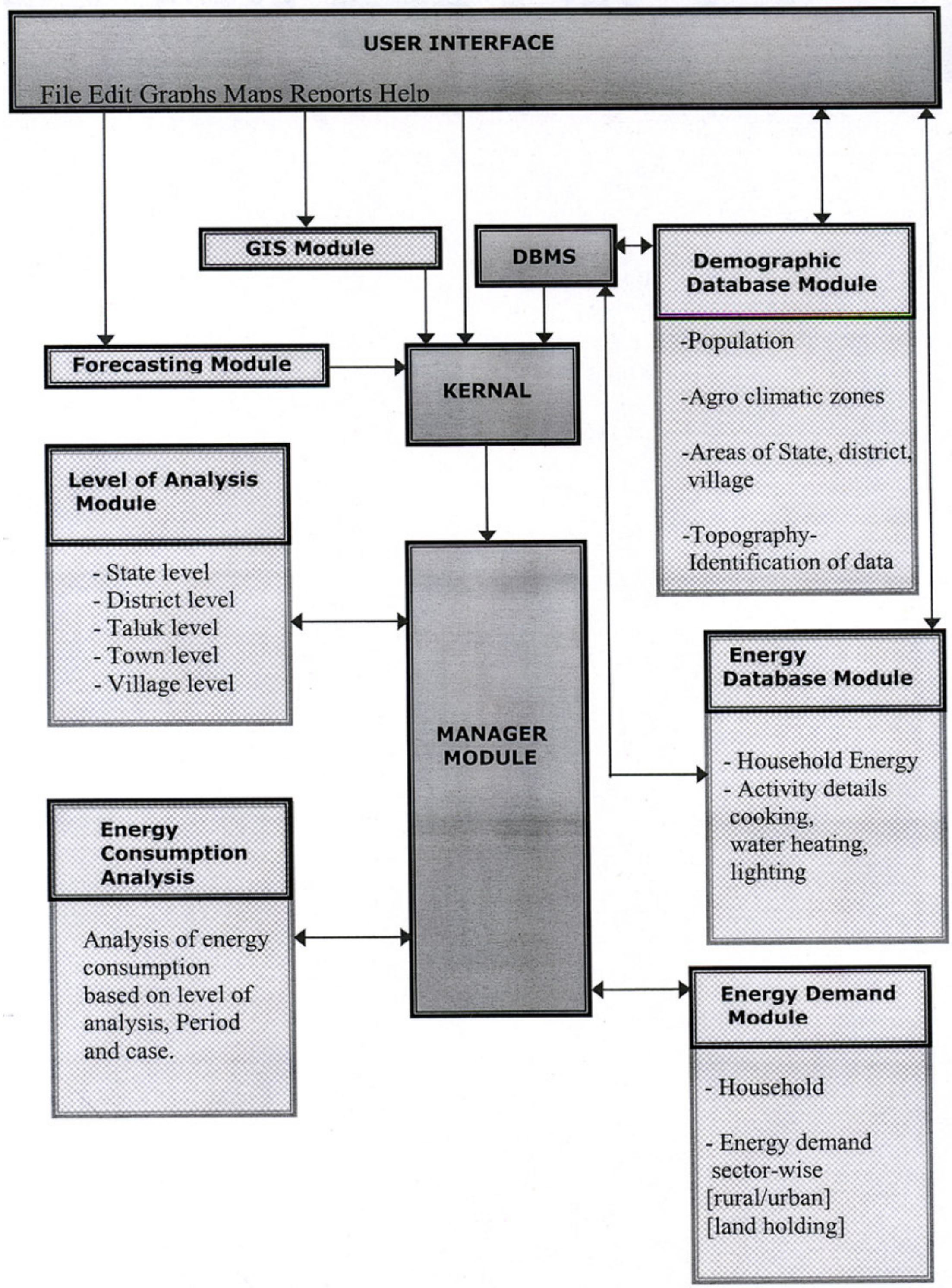


Fig. 1 — Design of decision support system for domestic energy demand assessment

Data Analysis

Per capita fuel consumption (PCFC) is computed to determine the fuel consumption pattern in various zones and to identify various parameters involved in the variation and level of fuel consumption for cooking and water heating. PCFC is given by,

$PCFC = FC/p$,

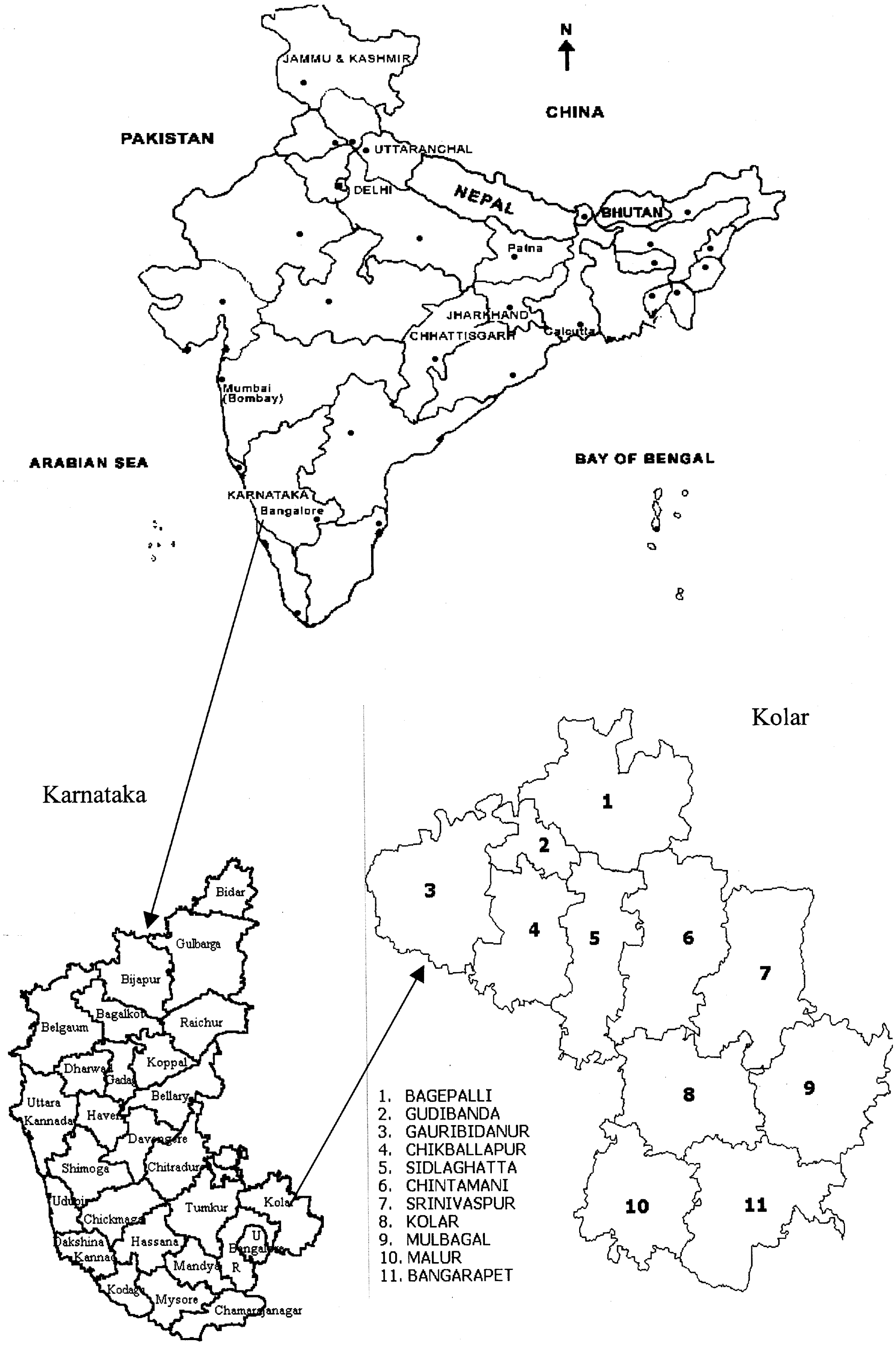


Fig. 2 — Study area: Kolar district, Karnataka State, India

Table 1 — Standard adult equivalents used in analysis

Family size y	Standard adult equivalent
Men 18-59	1.00
Women 18-59	0.80
Men >59	0.80
Women >59	0.80
Boys 5-18	0.50
Girls 5-18	0.50
Kids 1-5	0.35
Child <1	0.25

where FC = fuel consumed in kg/d and p = number of adult equivalents, for whom food was cooked.

Following factors were considered for the computation of PCFC:

i. More than one type of fuel is used for cooking and water heating in any household. The quantity of fuel consumed is determined by subtracting the weight of the remaining fuel from its initial weight. The daily consumption of different fuels is calculated separately from the fuel weights of the consecutive days.

ii. These daily consumption values in each household are converted to their equivalent dry weights, using the measured moisture content values, which are then converted into equivalent value using the net calorific value of each type of residue. These are added to get the daily energy consumption for each household.

iii. Daily energy consumption of each household is further converted to per adult energy consumption, using adult equivalent of the number of people, computed assuming the conversion factors (standard adult equivalents) as given in Table 1.

iv. For each family, daily per adult energy consumption is computed season-wise. The average value, standard deviation and maximum and minimum values are computed for annual and seasonal consumption.

v. The data is grouped, based on household income, landholding category, community and village separately. All the above parameters were computed for these groups[5].

Similarly, depending on the activities (cooking, water heating, lighting, etc.), the per-capita consumption per day is computed for electricity, kerosene, and LPG for 2500 households in Kolar district.

Biogas Usage

Biogas can be used for many purposes, mainly cooking and lighting in rural areas. It can be burned

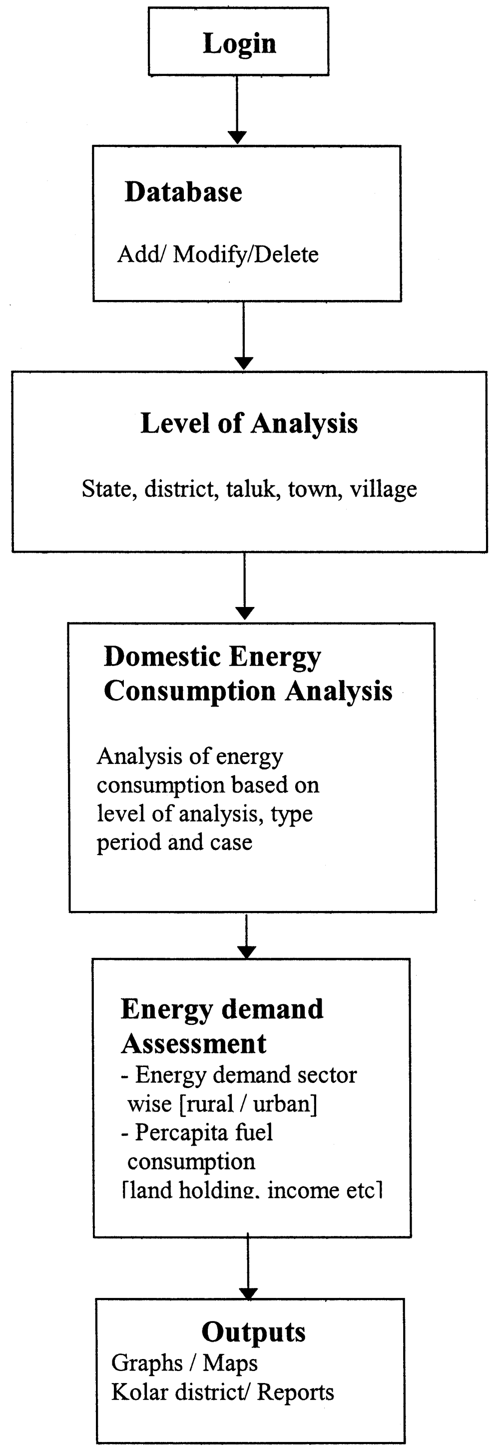


Fig. 3 — Navigation of DSS

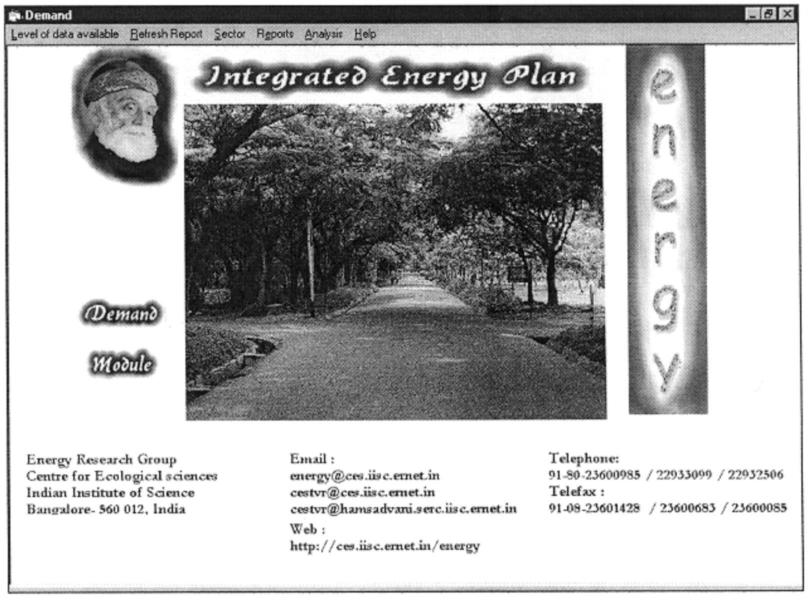


Fig. 4 — Domestic energy demand module

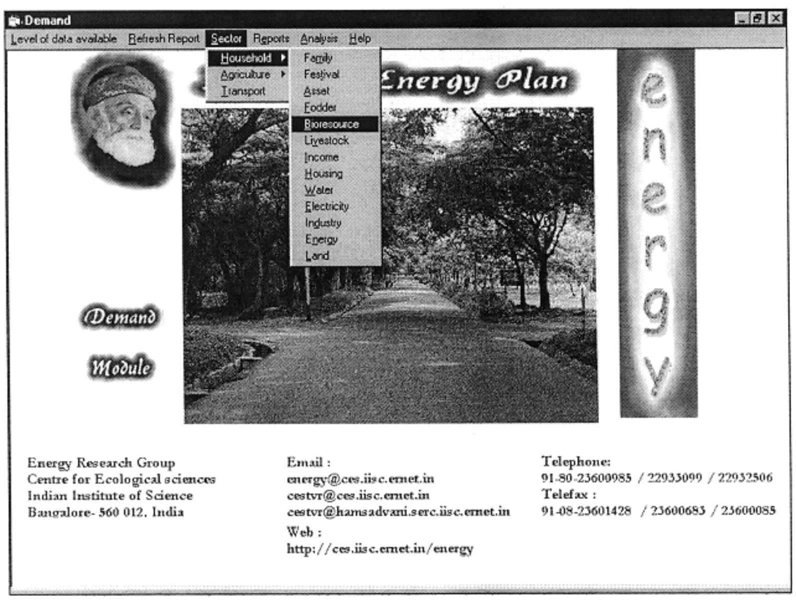


Fig. 5 — Sector-wise resource demand analysis

with a gas mantle or be converted to electricity, using dual mode engine. The per capita requirement of gas for domestic purposes such as, cooking and water heating, is in the range 0.34-0.43 m^3/d (efficiency of standard burner is about 60 %). The gas requirement to generate one unit of electricity (kWh) is about 0.54 m^3. The calorific value of gas is about 4713 kcal/m^3. Biogas potential assessment in Kolar district reveals that biogas can meet the cooking requirement of at least 20 per cent of the total district population.

Results

Survey data of Kolar district was implemented based on the flowchart for navigation of DSS (Fig. 3). An executable file was provided for this application and by executing, a form was displayed (Fig. 4) with level of analysis (village, taluk, district, and state), sector (domestic, municipal, industrial¸ transport, agriculture, etc.), reports (levels, sector-wise reports), analysis (per-capita fuelwood or kerosene consumption for cooking, water heating, etc.) and Help menu

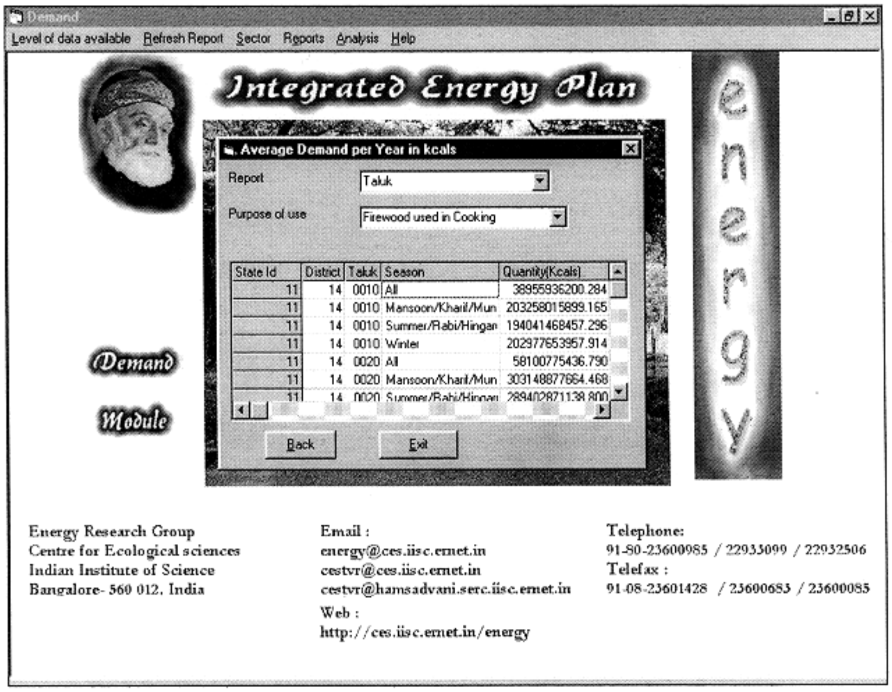
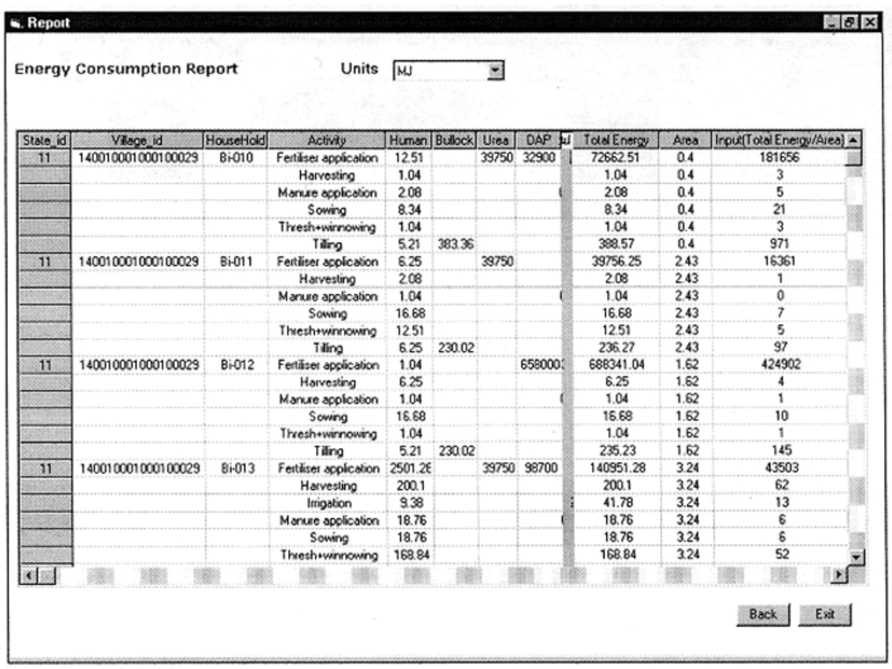


Fig. 6—Computation of energy demand/capita/d



State_id	Village_id	HouseHold	Activity	Human	Bullock	Urea	DAP	Total Energy	Area	Input(Total Energy/Area)
11	140010001000100029	Bi-010	Fertiliser application	12.51		39750	32900	72662.51	0.4	181656
			Harvesting	1.04				1.04	0.4	3
			Manure application	2.08				2.08	0.4	5
			Sowing	8.34				8.34	0.4	21
			Thresh+winnowing	1.04				1.04	0.4	3
			Tilling	5.21	383.36			388.57	0.4	971
11	140010001000100029	Bi-011	Fertiliser application	6.25		39750		39756.25	2.43	16361
			Harvesting	2.08				2.08	2.43	1
			Manure application	1.04				1.04	2.43	0
			Sowing	16.68				16.68	2.43	7
			Thresh+winnowing	12.51				12.51	2.43	5
			Tilling	6.25	230.02			236.27	2.43	97
11	140010001000100029	Bi-012	Fertiliser application	1.04			658000	688341.04	1.62	424902
			Harvesting	6.25				6.25	1.62	4
			Manure application	1.04				1.04	1.62	1
			Sowing	16.68				16.68	1.62	10
			Thresh+winnowing	1.04				1.04	1.62	1
			Tilling	5.21	230.02			235.23	1.62	145
11	140010001000100029	Bi-013	Fertiliser application	2501.26		39750	98700	140951.28	3.24	43503
			Harvesting	200.1				200.1	3.24	62
			Irrigation	9.38				41.78	3.24	13
			Manure application	18.76				18.76	3.24	6
			Sowing	18.76				18.76	3.24	6
			Thresh+winnowing	168.84				168.84	3.24	52

Fig. 7—Activity-wise energy consumption

options. Fig. 5 allows the user to enter the data resource-wise (fuel wood, electricity, etc.) sector-wise (domestic, agriculture, transport, etc.), and activity-wise (cooking, heating, lighting, etc.). Fig. 6 depicts the form for computation of region-wise (village/taluk/district) energy demand. Similarly, Fig. 7 provides the activity-wise energy consumption. Fig. 8 shows the biogas consumption in Kolar district for all the four cases depending on the resource availability.

Average per-capita consumption of fuel wood (Table 2) for cooking ranges from 0.69±0.34 in Bangarpet (summer) to 1.42±0.27 kg/capita/d in Gudi-

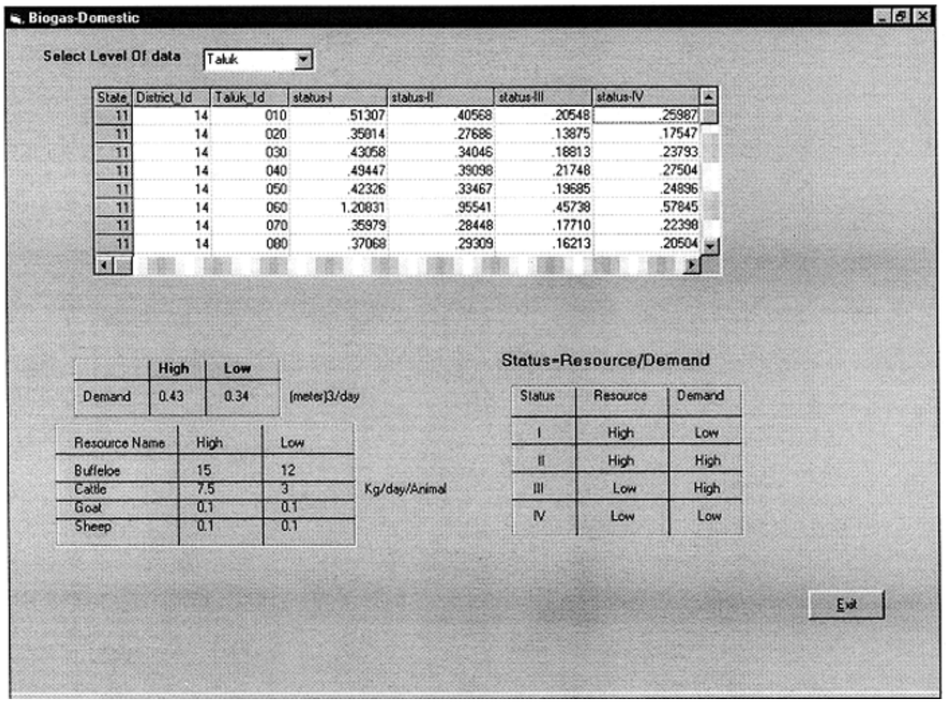


Fig. 8—Biogas status for selected level (state, district, taluk, village)

Table 2 — Average per-capita consumption of fuel wood for cooking and water heating

Taluk	Fuel wood for cooking kg/capita/d			Fuel wood for water heating kg/capita/d		
	Monsoon	Summer	Winter	Monsoon	Summer	Winter
Bagepalli	1.35±0.12	1.31±0.11	1.36±0.14	0.68±0.25	0.66±0.22	0.70±0.26
Bangarpet	0.75±0.32	0.69±0.34	0.71±0.35	0.62±0.37	0.59±0.26	0.62±0.37
Chikballapur	1.29±0.47	1.23±0.45	1.29±0.46	0.57±0.30	0.50±0.24	0.57±0.30
Chintamani	1.25±0.26	1.25±0.26	1.25±0.26	0.11±0.07	0.11±0.07	0.11±0.07
Gauribidanur	1.37±0.66	1.24±0.57	1.37±0.66	0.71±0.25	0.67±0.25	0.71±0.25
Gudibanda	1.42 ± 0.27	1.42 ± 0.27	1.42 ± 0.27	0.55±0.30	0.50±0.24	0.58±0.30
Kolar	0.83±0.48	0.78±0.43	0.83±0.46	0.49±0.36	0.39±0.28	0.50±0.35
Malur	0.75±0.48	0.78±0.43	0.74±0.46	0.61±0.26	0.55±0.26	0.61±0.26
Mulbagal	1.27±0.47	1.22±0.45	1.26±0.46	0.55±0.30	0.50±0.24	0.58±0.30
Sidlaghatta	1.13±0.56	1.13±0.56	1.13±0.56	0.13±0.11	0.13±0.11	0.13±0.11
Srinivasapur	1.22±0.57.	1.13±0.48	1.21±0.57	0.66±0.42	0.59±0.32	0.66±0.42

banda (all seasons), while for water heating, it ranges from 0.11±0.07 in Chintamani (all seasons) to 0.71±0.25 kg/capita/d in Gauribidanur (monsoon & winter).

Analysis of the average per-capita consumption of electricity (Table 3) for cooking, water heating and lighting shows that electricity consumption for cooking ranges from 0.44±0.28 (summer) to 0.46±0.25 kWh/capita/month (monsoon and winter) in Kolar taluk. Consumption of electricity for water heating ranges from 0.2±0.08 in Kolar (all seasons) to 0.16±0.08 kWh/capita/month in Malur (all seasons) in Kolar district. Electricity for lighting purpose ranges from 5.17±2.16 (Gudibanda) to 6.57±4.07 kWh/capita/month (Sidlaghatta) in Kolar district.

Average per-capita consumption of kerosene (Table 4) for cooking, ranges from 0.44 ±0.16 in Gauribidanur (monsoon and winter) to 1 ± 0.76

Table 3 — Average per-capita consumption of electricity for cooking, water heating and lighting

Taluk	Electricity for cooking kWh/capita/month			Electricity for water heating kWh/capita/month			Electricity for lighting kWh/capita/month
	Monsoon	Summer	Winter	Monsoon	Summer	Winter	All seasons
Bagepalli							5.33 ± 1.86
Bangarpet	0.39 ± 0.21	0.35 ± 0.22	0.39 ±0.21				5.99 ± 2.23
Chikballapur	0.49 ± 0.24	0.45 ± 0.27	0.48 ±0.28				5.7 ± 2.27
Chintamani							5.30 ± 2.16
Gauribidanur							5.47 ± 2.22
Gudibanda							5.17 ± 2.18
Kolar	0.46 ± 0.25	0.44 ± 0.28	0.46 ±0.25	0.2 ± 0.08	0.2 ± 0.08	0.2 ± 0.08	6.02 ± 4.68
Malur	0.36 ± 0.22	0.34 ± 0.18	0.38 ±0.23	0.16 ± 0.08	0.16 ± 0.08	0.16 ± 0.08	6.15 ± 4.26
Mulbagal							5.99 ± 4.13
Sidlaghatta							6.57 ± 4.07
Srinivasapur							6.01 ± 4.26

Table 4 — Average per-capita consumption of kerosene for cooking, water heating and lighting

Taluk	Kerosene for cooking l/capita/month			Kerosene for water heating l/capita/month			Kerosene for lighting l/capita/month		
	Monsoon	Summer	Winter	Monsoon	Summer	Winter	Monsoon	Summer	Winter
Bagepalli	0.9 ± 0.32	0.85 ± 0.28	0.9 ± 0.31	0.8 ± 0.28	0.8 ± 0.28	0.8 ± 0.28	0.65 ± 0.11	0.71± 0.13	0.67± 0.11
Bangarpet	0.57 ± 0.20	0.58 ± 0.21	0.57 ±0.20	0.91 ± 0.25	0.91 ± 0.25	0.91 ± 0.25	0.62 ± 0.29	0.62 ± 0.29	0.62 ± 0.29
Chikballapur	0.76 ± 0.46	0.75 ± 0.44	0.75 ± 0.44	0.19 ± 0.70	1.19 ± 0.70	1.19 ± 0.70	0.67 ± 0.13	0.67 ± 0.13	0.67 ± 0.13
Chintamani	1 ± 0.76	0.99 ± 0.77	1 ± 0.76				0.73 ± 0.10	0.73 ± 0.10	0.73 ± 0.10
Gauribidanur	0.44 ± 0.16	0.45 ± 0.18	0.44 ± 0.16				0.57 ± 0.21	0.57 ± 0.21	0.57 ± 0.21
Gudibanda	0.84 ± 0.73	0.79 ± 0.75	0.84 ± 0.73				0.64 ± 0.05	0.74 ± 0.08	0.64 ± 0.05
Kolar	0.7 ± 0.23	0.69 ± 0.23	0.7 ± 0.23	0.82 ± 0.60	0.78 ± 0.66	0.83 ± 0.59	0.42 ± 0.11	0.43 ± 0.11	0.42 ± 0.11
Malur	0.69 ± 0.22	0.67 ± 0.23	0.69 ± 0.22	0.48 ± 0.28	0.44 ±0.22	0.48 ± 0.28	0.39 ± 0.10	0.4 ± 0.10	0.4 ± 0.10
Mulbagal	0.87 ± 0.43	0.87 ±0.43	0.87 ± 0.43						
Sidlaghatta	0.63 ± 0.29	0.63 ± 0.29	0.63 ± 0.29				0.63 ± 0.29	0.63 ± 0.29	0.63 ± 0.29
Srinivasapur	0.57 ± 0.26	0.57 ± 0.26	0.58 ± 0.26				0.47 ± 0.12	0.47 ± 0.12	0.47 ± 0.12

Table 5 — Average per-capita consumption of LPG for cooking

Taluk	LPG for cookingkg/capita/month		
	Monsoon	Summer	Winter
Bagepalli			
Bangarpet	0.2 ± 0.13	0.2 ± 0.13	0.2 ±0.13
Chikballapur	0.31 ± 0.20	0.22 ± 0.09	0.22 ± 0.09
Chintamani			
Gauribidanur			
Gudibanda			
Kolar	1.03 ± 1.35	1.03 ± 1.35	1.03 ± 1.35
Malur	0.18 ± 0.05	0.18 ± 0.05	0.18 ± 0.05
Mulbagal			
Sidlaghatta			
Srinivasapur	0.57 ± 0.26	0.57 ± 0.26	0.58 ± 0.26

Table 6 — Average per-capita consumption of biogas for lighting

Taluk	Biogas for lightingm^3/capita/day		
	Monsoon	Summer	Winter
Bagepalli			
Bangarpet	0.61 ± 0.71	0.61 ± 0.71	0.61 ± 0.71
Chikballapur	0.7 ± 0.11	0.69 ± 0.10	0.71 ± 0.10
Chintamani			
Gauribidanur			
Gudibanda			
Kolar	0.6 ± 0.29	0.6 ± 0.29	0.6 ± 0.29
Malur	0.76 ± 0.28	0.76 ± 0.28	0.76 ± 0.28
Mulbagal			
Sidlaghatta			
Srinivasapur			

l/capita/month in Chintamani (monsoon and winter) and for lighting it ranges from 0.39 ±0.1 in Malur (monsoon) to 0.74 ±0.08 in Gudibanda (summer). Average per-capita consumption of LPG for cooking (Table 5) ranges from 0.18 ±0.05 in Malur (all seasons) to 1.03 ±1.35 kg/capita/month in Kolar (all seasons). Biogas consumption (Table 6) for lighting, ranges from 0.6 ±029 in Kolar (all seasons) to 0.76 ±0.28 m^3/capita/d in Malur (all seasons).

Conclusions

Among the 11 taluks, 2500 randomly selected households from 137 villages of Kolar district were studied. Survey shows that most of them still use traditional fuel wood stoves for cooking (97.92 %) and water heating (98.3 %). Average fuel wood consumption for cooking ranges from 0.69±0.34 to 1.42±0.27 kg/capita/d, while, for water heating, it ranges from 0.11±0.07 to 0.71±0.25 kg/capita/d. Analysis of other sources of energy for domestic purposes shows that electricity, kerosene, LPG, and biogas are used for cooking, water heating and lighting in a rational manner.

Most energy planning exercises are carried out with aggregate data at the national level. At regional level namely village, block or district, there have been fewer efforts for energy planning. Energy resources and demand are spatially distributed. Aggregated analysis does not capture the spatial variation in supply and demand. DSS assists in analyzing the energy sources and demand spatially. The technologies and methods used to develop and deploy DSS to aid in domestic energy consumption make work easier for a decision maker. The possibility of quickly accessing and processing large spatial databases over high speeds, offers a tremendous improvement. In spite of rapidly advancing computer technology and the proliferation of software for decision support, relatively a few DSS have been developed for assessment of energy demand. DSS with a user-friendly GUI provides user an easy access of data analysis and the design and evaluation of domestic energy consumption strategies. The entire framework is designed in such a way that, user is provided with helpful tips and context-sensitive help options. Energy DSS will improve the quality of decision making at the block, district, and State level and enable the analysis and understanding of energy impacts of various decisions.

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