ELECTRICITY DEMAND ESTIMATION FOR VILLAGE ELECTRIFICATION

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ABSTRACT

In order to size and select decentralised renewable energy systems for village electrification, it is necessary to estimate the electricity demand for non-electrified villages. This paper presents a framework for estimating the electricity load curve for a village based on an end-use method. The electrification module is illustrated for a village in Gangajalghati in West Bengal. The peak load, average load and daily load curves during summer and winter are computed in 2005 for this village. The electrification module developed is a part of a decision support system (DSS) for energy planning and can be used for estimating the electricity requirements for any village (using the census data) and will be a useful tool in energy planning [1]

KEYWORDS

Electricity demand, Peak load, Appliance ownership, DSS.

INTRODUCTION

A large number of Indian villages still do not have access to electricity. In many cases, the costs of extending the grid to the village are prohibitive. Decentralised renewable options like biomass gasifier, solar photovoltaic or wind power could be viable for electrifying many of the non-electrified villages. In order to design and size renewable energy systems, it is essential to estimate the electricity demand for a village. This paper describes a decision support system (DSS) for electricity demand estimation.

The electricity module is a part of the DSS for energy planning (details about the framework are available in paper [2]) developed and illustrated for Bankura district in West Bengal. In Bankura district, 49% of the villages were not electrified till 1991 [3]. Discussions with the district officials and the Zilla Parishad representatives revealed that it is unlikely that all villages would be electrified even in the next 10 years. The electrification module provides the user the ability to synthesize the load curve of a village or a group of villages based on the population, income distribution, irrigation pattern, and industry (if any). Different supply options can be used to meet the estimated load curve.

METHODOLOGY

The methods normally used for demand forecasting are time series methods, econometric and end-use methods [4]. In the case of village electrification, data availability and disaggregation capability rules out time series and econometric methods. An end-use method permits incorporation of efficient devices, income transitions and facilitates easy construction of what-if scenarios. Figure 1 shows a schematic of the framework used for the electricity demand module. The residential electricity demand is estimated based on appliance ownership data (for different income classes), technology characteristics of appliances and usage pattern. The appliance stock matrix [AS] is given as

$$[AS]_{I\times M} = (N_H/100)\ [\ f\ ]_{I\times 4}\ [AO]_{4\times M} \qquad (1)$$

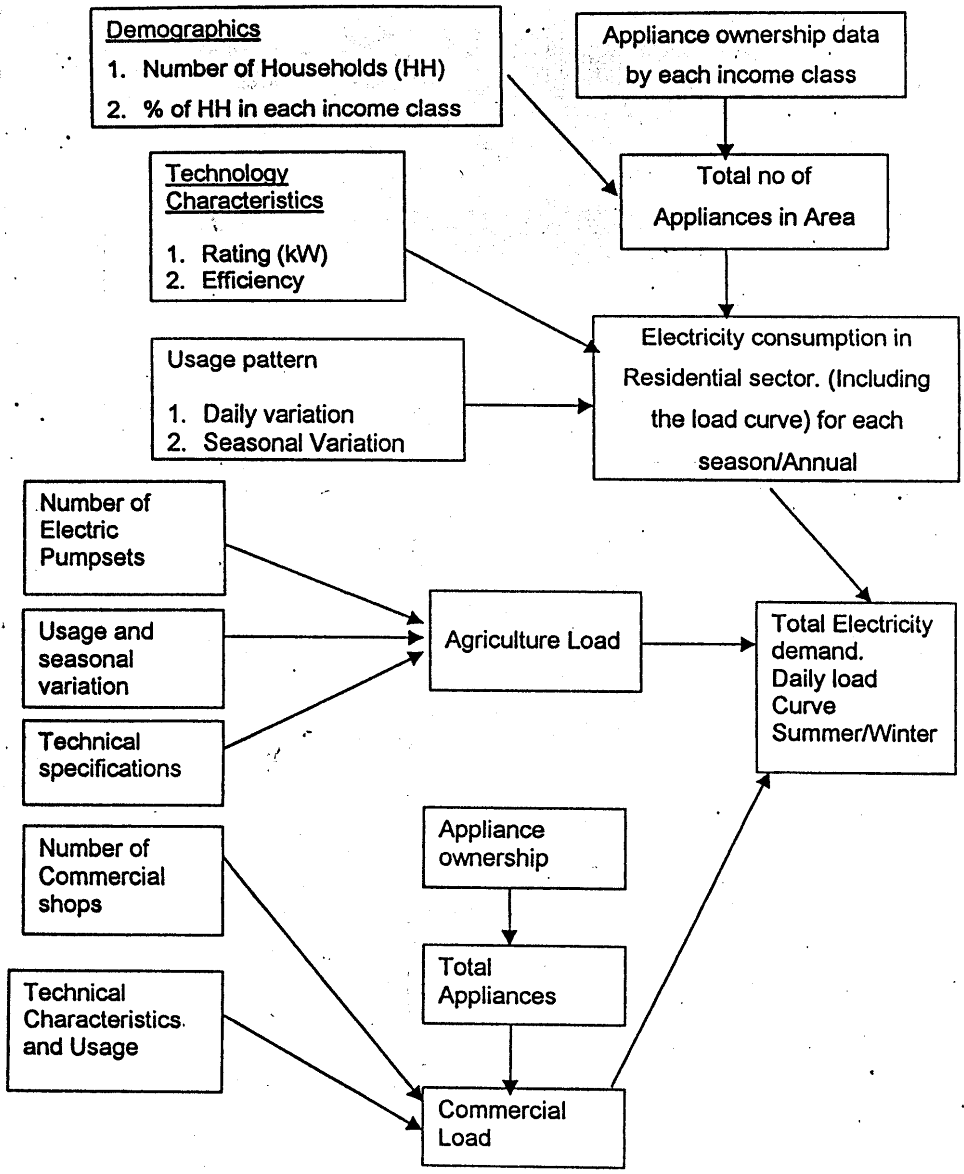

Fig. 1 Flow chart for village electrification

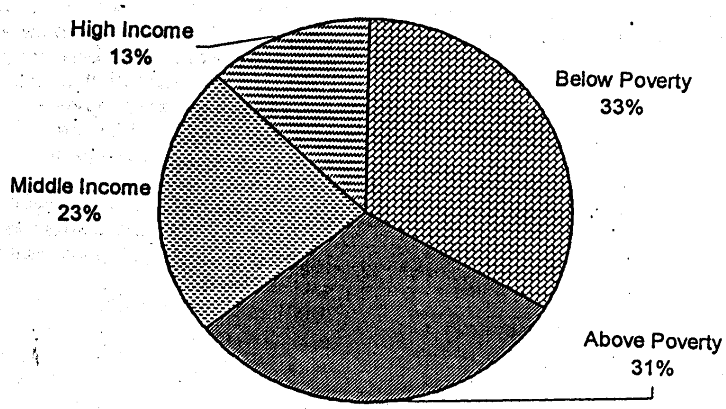

Fig. 2 Income class distribution in Rajamele village in 1994.

where,

[f] is the fraction of households in the 4 different income classes

Viz. [f_{BP} f_{AP} f_{MI} f_{HI}],

The appliance ownership [AO_{ji}] matrix is the number of appliance i for 100 households of the jth income category i = 1,2,3,.....M -different appliance categories.

For example, if i=1 represents incandescent of 60W standard rating, AO_{21} represents the number of incandescent per 100 households in the Above Poverty income class. The appliance stock matrix will be multiplied by the rating R_i and the utilization factor matrix U_{it}, where t = 1,2,3,.....24 for each hour of the day to get the hourly consumption(EL_t)

$$[EL_t]_{1x24} = [\, R_i\, AS_i\,]_{1xM}\, [U_{it}]_{Mx24} \qquad (2)$$

The hourly electricity usage is summed up to obtain the total seasonal electricity consumption EL_s. where D is the total number of days in one season. Different seasons will have different utilization factor matrices. The ratings of individual equipment are obtained from technology characteristics (manufacturer data).

The usage pattern and the appliance ownership data can be obtained from household surveys. The fraction of households in different income categories can be obtained from secondary data (census, village level indicators) or by using occupation as a proxy for income class (using the occupation-income matrix) as proposed by paper [2]).

In a similar fashion, the agricultural demand (for irrigation) is computed based on the number of pumpsets, proportion to be electrified, head and

$$ELs = \sum_{d=1}^{D} \sum_{t=1}^{24} EL_t \qquad (3)$$

flow rate for the pump-sets, usage and season pattern (based on the timing when irrigation is required which is dependent on crop calendar).

In the DSS developed there is also an industry module, which includes small scale industries like brick kiln, bell metal, rice mills, flour mills and oil mills apart from commercial establishments. In the case of non-electrified villages, it is assumed that there are no industries, only commercial establishments whose load patterns are to be added to the village load.

CASE STUDY: RAJAMELE VILLAGE

For illustration of the village electrification module, a non-electrified village, Rajamele, in Gangajalghati block in Bankura district in West Bengal has been selected. Village Rajamele had a population of 1526 in 1994 and an area of 348 hectares. The population density is 437persons/km^2 (similar to the average population density of the study area-district Bankura which is about 410 persons/km^2) [3]. The income class distribution for Rajamele village is shown in Figure 2. The appliance ownership data is obtained by analogy with surveys carried out is similar villages with access to electricity. It is expected that the households below poverty cannot afford an electricity connection. Hence the module assumes that there are no electric appliances in the below poverty households.

A household survey of 163 households in Bankura district was carried out by the National Resource Data Management System (NRDMS) team of the Centre for Systems Analysis for Development (CASAD) in Bankura district in 1996. The appliance ownership data obtained from the survey is summarised in Table 1. The appliance ownership data obtained for towns in Maharashtra [5] and have been used as upper bounds to crosscheck the survey. The appliance rating data used is shown in Table 2.

Assumptions for load estimation of Agriculture and commercial sector are shown in Table 3.The demand estimation is to be done for a target year in the future. To estimate the future population, a population growth rate of 1.1% per year was taken (based on the past trend) and demand estimates were obtained for 2005.

Table 1 Number of Electric appliances / 100 Households.

APPLIANCES	AP	MI	HI
Incandescent Lamp	150	200	250
Fluorescent Tube	50	200	350
Ceiling Fan	50	150	180
Television	15	70	90
Refrigerator	0	5	28
Others Appliances	0	4	20

Appliance ownership is zero for below poverty income class.

Table 2 Appliance ratings used for calculation.

Appliance	Rating (W)
Incandescent Lamp	60
Fluorescent Tube	54 (40 + 14)
Ceiling Fan	65
Television	80
Refrigerator	100

Table 3 Assumptions for Electricity estimation of Agriculture and commercial load.

No. of pump sets to be electrified	5
Capacity of pump considered (HP)	3
Yearly hours of operation	1000
Motor Pump efficiency	0.5
Number of commercial shops	30
Connected load per shop (W)	240

ELECTRICITY DEMAND FOR RAJAMELE VILLAGE IN 2005

Table 4 shows the electricity demand for Rajamele village in 2005. Figure 3 shows the daily load curve for Rajamele village in 2005 during summer. Similar load curves have been obtained for winter. The peak load occurs during the summer is 58kW. The average annual load factor is 32%. The residential load contributes the major proportion of the total load.

Table 4 Rajamele Electricity demand.

Non cooking electricity consumption (MWh)	141
Electricity requirement for agriculture (MWh)	13
Electricity requirement for commercial shops (MWh)	8
Total electricity requirement (MWh)	162
Daily Peak Load (kW)	58

In case the village has a small-scale industry the load factor would improve. If an electricity supply system is to be designed to meet the requirements of this village it must be able to

- meet a peak demand of 58kW and an average demand of 18kW. This information will be useful to size and evaluate alternative supply options for Village Electrification.

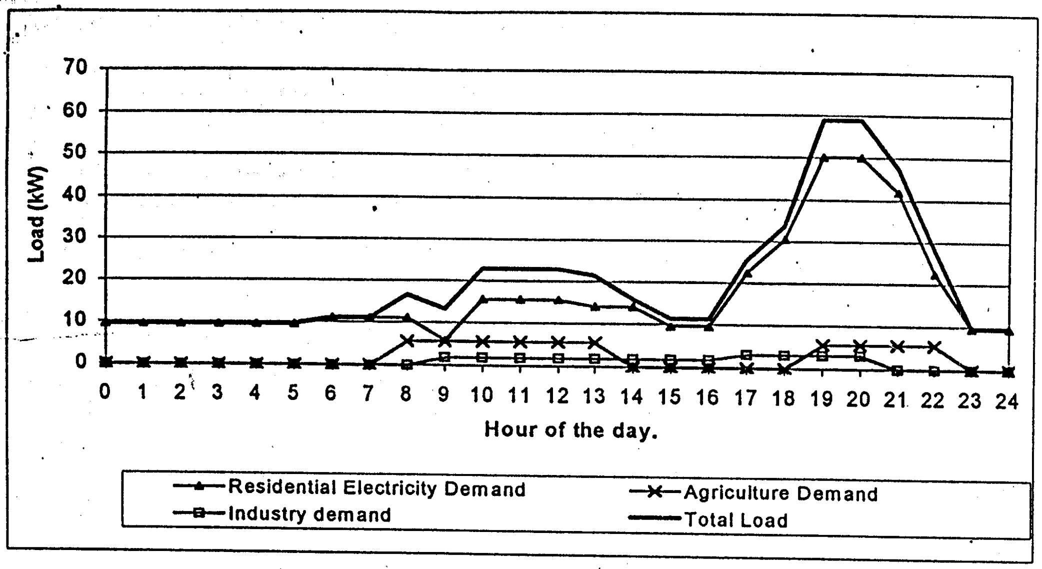

Fig. 3 Daily load curve for Rajamele village in Summer in 2005

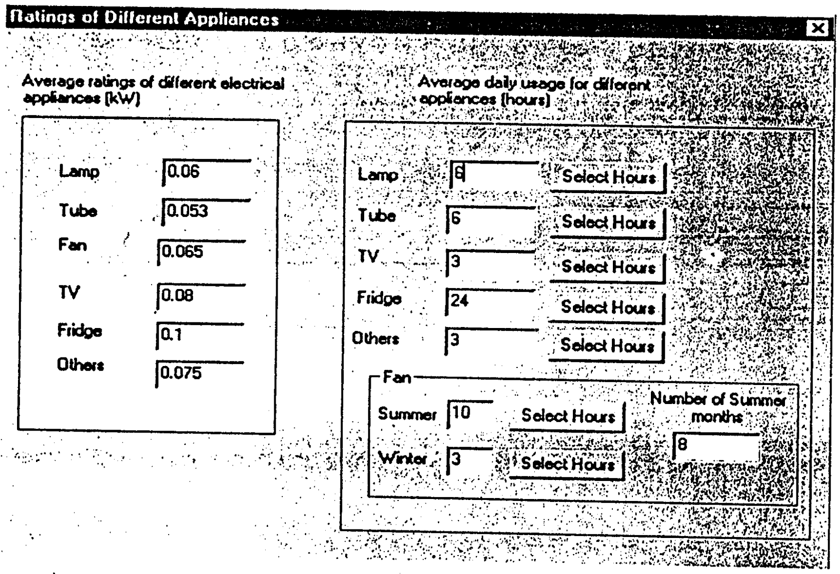

Fig. 4 Sample Input Menu of the DSS for Electricity demand estimation For village electrification.

DISCUSSION AND CONCLUSIONS

The methodology proposed in this paper has been implemented as a module in the Decision Support System using VC++ (with user friendly menus).A sample input menu of the DSS is shown in Figure 4.This permits the automatic calculation of the load curves for non-electrified villages from the census and survey data. This tool will be useful to energy planners to estimate the future demands of rural areas and decide on how to meet these requirements. Measurements of individual equipment load profiles will enhance the accuracy of the demand estimates of the electrification module. The demonstration of the use of these demand estimates has been made to size and evaluate alternative renewable energy options [6]. The electrification module developed is replicable and can be used for any village or block in India.

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NOMENCLATURE

[AS]	Appliance stock matrix
[f]	Fraction of households in four different classes
$[AO_{ij}]$	Appliance ownership matrix
BP, AP	Below poverty, Above poverty
EL_t, EL_s	Hourly electricity consumption, Seasonal electricity consumption(kWh)
MI, HI	Middle income, High Income
N_H	Total number of households in the area
R_i	Rating of an equipment

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