As. J. Energy Env. **2005**, 6(04), 232-240

Asian Journal on Energy and Environment

ISSN 1513-4121

Available online at www.asian-energy-journal.info

Optimal Mix of Rural Energy Using Fuzzy Logic for Shops and Establishments

Chinmoy Jana*

Faculty Member , Energy Management Stream , Department of Public Systems Management , Indian

*Author to whom correspondence should be addressed, email: chinmoviana@vahoo.com

---

Abstract: The energy resource allocation strategy is normally overlooked in rural energy use due to lack of information and absence of realistic planning approach. Locally available energy resources are used abundantly and the indigenous technologies have lost their values. In this study, the different types of shops and establishments like offices, health service units etc, are surveyed and information is analysed. Energy is required for lighting and cooking in the shops, hotels, hostels, health centres etc. Lighting is the major task in the offices whereas its duration of use is different from the shops. All possible sources are used in this study. Minimisation of total cost of direct energy, minimisation of non-local sources of energy and maximisation of overall efficiency are adopted as objective functions and so Multi Objective Fuzzy Linear Programming technique is used to achieve a best compromised solution of these three objective functions. The developed model is applied for testing the case of Narayangarh Block of West Medinipur District in West Bengal State of India. The result shows that kerosene is still the most economically viable source for lighting while electricity is the most preferred source for qualitative outcome. Spy system has the potential to replace diesel fueled generator sets which are commonly used for lighting purposes in the shops, establishments, market areas, festivals etc.

Keywords: Shops and Establishments, Fuzzy Logic, Multi Objective, Energy Planning, SPY System.

Introduction

A large section of users of energy in rural sector consists of a variety of shops making commercial transactions, different establishments like offices, schools, health service units, veterinary centres, clubs, libraries, recreation units etc. The tasks performed by these units are not same and the time schedules and duration of consumption for those tasks vary widely.

Usually the shops require energy for four hours lighting in the evening. Other important end uses are cooking in the hotels, sweet shops, restaurants etc and operating ovens for preparation of various food items or consumer goods. In the villages, rarely any machine is operated in the shops for preparing food, clothes or other consumer items. Kerosene'and electricity are common sources for lighting though diesel fueled generators are used occasionally to serve a cluster of shops. For the purpose of cooking in shops, firewood and coal are common sources for hotels and sweet shops though kerosene is often used in tea stalls, restaurants etc along with coal. LPG fueled ovens are used in a few sweet shops and restaurants.

Lighting is the major task for offices, health centres, hostels, clubs and recreation centres etc. The duration of lighting per day is normally 10 hours in offices and 4 to 5 hours in other establishments. Lighting facilities are absent in the village schools but the school hostels require huge supply of energy for cooking and lighting. The task of cooking is performed by using coal and firewood. Use of firewood depends largely on the proximity and price of the source in the local area. Though Spy system has enough scope of use for lighting in various establishments, it has not been done so mainly due to the constraints of high investment cost and non-existence of repair and maintenance facilities. Health service units and veterinary centres need energy for cooking dietary items, operating machines like x-ray etc, running some freezing devices and others. Electricity and LPG are most suitable sources for these tasks. However, coal and kerosene are also used where more convenient sources are not available. Lighting points vary from 5 to 20 numbers depending on the size or order of the establishment and duration of supply ranges from 4 to 24 hours. Lower order units like health sub-centres, Maternity units, clinics, Artificial Insemination Centres etc often function without electric service connections.

Taking an overall view, it has been observed that in the rural areas the proximity to source and price of energy source are most important factors in practising the local level demand-supply management. Environmental issues often become the causes of concern for micro-level energy planning in rural areas.

In 1991 Joshi worked on resource allocation for domestic sector of rural areas in Nepal. Like some other researchers he has also used Linear Programming (LP) with single objective and in most cases that is minimisation of total cost. Narshiman (1980) handled the exact but imprecise data for ormulation of a fuzzy decision making model. Chetty and Subramanian [1988] used multi objective Goal Programming (GP) to energy planning to prioritise the multiple objectives towards solving the problems. It has become more obvious that for comparing different ways of action as to their desirability and for judging the suitability, the minimisation of surpluses over the aspiration levels of objectives may be maximised [Zimmerman 1978]. In recent years [1999], Jana et al [2000, 2004] used Fuzzy Linear Programming for obtaining solution in multi objective energy planning for different sectors.

Analysis of Situation

For obtaining a detailed information on energy consumption and to release the problems there of, it was necessary to organise a survey of commercial users and institutions. Such a survey could cover the types of establishment, fuel use that would be classified by source, end use and type of equipment, any local factor relevant to fuel choice (including fuel prices) etc. Data collection involved monitoring and estimation of energy consumption and identification of potential savings since most of the respondents are illiterate or little educated and unaware of many issues of concern.

The collection of data from govt, offices, hostels, health centres etc posed less problems since respondents were educated and information could mostly be provided from recorded sources.

There are different types of shops for selling different items and for providing different services. This obviously implies that they are of different sizes. In this Block the shops are categorised by variations in needs of energy, i.e., minimum number of lighting points required. Pan (betel) shops, fruits or flower shops, small groceries.stationary shops etc need only 1 lighting point whereas some shops like tea stalls, small medicine shops, ready-made cloth stores, fertliser shops etc require at least two lighting points. Big cloth stores, medicine stores, sweet shops etc need 4 lighting points. All the above shops need at least 4 hours on an average of lighting for three hundred days per year. A few big shops like hotels, large cloth stores etc need 10 or more lighting points. In this sector, cooking is also a part of task for school hostels, hotels, tea stalls, sweet shops, health centres etc.

The biggest Community Development Block of India, Narayangarh Block, which lies in West Medinipur district of West Bengal State in India, has been selected for testing the viability of this micro-level planning structure. It lies between 22° 0' Nand 22° 15" N latitudes and 88° 15' E and 87° 30' E longitudes. The Block has 16 Gram Panchayats (GP) consisting of 517 villages including 54 uninhabited villages. It has 259668 population with a net density 515 persons per square km.

In the study area, there are 900 small shops each of which needs only one lighting point for 4 hours a day. These are mostly situated in the villages where electricity is not available. Some pan (betel) shops are too small and they use kerosene lamp in the evening and do not show the urge for electric connection. Some groceries, small cloth centres, stationary, medicine shops etc are situated in the villages or market places and they use all the sources available for lighting including occasional connections to diesel generator sets. Normally, in the larger and progressive villages or places like growth centres, some big cloth stores, shoe shops etc are situated which need about 4 lighting points in the evening. Most of the Govt. offices, GP offices, banks, cooperatives etc need more than ten light points during the office hours. In the Block there are 400 such establishments including 17 commercial banks, 4 cooperative banks. 1 land development bank, 45 cooperative societies etc. Besides, there are school hostels, health centres, cinema halls etc which need more than 10 lighting points.

In Narayangarh Block, there are one hospital (BPHC), IS primary health centres, 3 subsidiary health centres and 8 other units providing health facilities. The present facility though not numerically very poor, is far from adequate for the huge population of the Block. The BPHC needs more than 50 lighting points for 365 days with 24 working hours per day. The PHCs mainly provide outdoor facilities and need about 10 lighting points for 300 days with 8 hours of working period per day. As per the information gathered from the villagers, almost all SHCs are running without doctors and beds. Only some paramedical staff or a visiting doctor perform the referral service.

Mathematical Structure

Minimisation of (1) cost, (2) non-local sources of energy used and (3) total energy used are the three objectives in the model of allocation of energy sources for this sector. The decision variables X_{ijkl} represent the quantities of fuel source i through the device i for lighting (k=l) and cooking (k=2) tasks at the types of users (1). The Source-Device-TaskUser combinations used in solving the model is given in table -1.

Table-1: Source-Device-Task -User Combinations Considered in This Sector

(i) Source	(j) Device	(k) Task	(I) User
(1) Coal	(6) Traditional chullah	(2) Cooking	(3) Hotel
			(4) Hostel
			(5) Sweet Shop
(2) LPG	(7) Traditional oven		(3) Hotel
			(5) Sweet Shop
(3) Kerosene	(8) Stove		(6) Tea Stall
	(1) Lamo	(1) Lighting	(0) All Units
	(2) Hurricane		
(4) SPY	(5) CFL		
(5) Firewood	(4) Chullah	(2) Cooking	(3) Hotel
			(4) Hostel
			(5) Sweet Shop
			(6) Tea stall
	(9) Machinery	(3) Operation of Machines	(10) Bakery
(6) Electricity	(3) Bulb	(1) Lighting	(0) All Units
	(4) Tube		
	(5)CFL		
(7) Diesel	(10) Generator set	(I) liehtino	(0) All units

The structural equations and expressions depicting the model are as follows:

Objective - 1: Minimization of Cost for Direct Energy

$$O_1 = Min \sum_i \sum_j \sum_k \sum_l C_{ijkl} x_{ijkl} \qquad (1)$$

Where C_{ijkl} is the unit cost of decision variables X_{ijkl}

Obiective-2: Minimization of Non-local Sources of Energy

$$O_2 = Min\sum_i\sum_i\sum_k\sum_l R_{ijkl}x_{ijkl} \quad \forall\ i = 1, 2, 3, 6 \text{ and } 7 \qquad (2)$$

Where R_{ijkl} is the conversion factor of decision variables X_{ijkl}

Objective -3: Minimization of total use of Energy

$$O_3 = Min\sum_i\sum_i\sum_k\sum_l R_{ijkl}x_{ijkl} \qquad \forall\ i \qquad (3)$$

subject to:

$$\sum_i\sum_j x_{ijkl} \geq D_{kl} \qquad (4)$$

Where D_{ki} are the demand for k th task of 1 th user

$$\sum_j\sum_k\sum_l x_{ijkl} \leq A_i \qquad \forall\ i \qquad (5)$$

Where A_i are the availability of i^{th} source in the system.

$$\sum_i\sum_j x_{ijkl} \geq d^{we} \qquad \text{for } i \neq 6, k = 1 \text{ and } l = 0 \qquad (6)$$

Where d^{we} is the demand of lighting points where electricity is not available.

$$\sum\sum x_{ijkl} \leq A_{ik} \qquad \text{for } i=6 \text{ and } k = 1 \qquad (7)$$

Where $A^{i\,k}$ is availability of i^{th} source for k^{th} task.

$$\sum_i x_{ijkl} \geq d_i \qquad \text{for } i = 3, k = 1 \text{ and } l = 0 \qquad (8)$$

Where d_j is the demand where only kerosene is available.

Quantification of Demand

The demand for lighting purposes by different units in this sector has been estimated on the basis of number of points, hours of lighting and days of functioning in a year as detailed below in table 2:

Thus in the Block, the total demand of energy for lighting purposes is estimated to be 21182 thousand hours of lighting of which a maximum of 18566 thousand hours of lighting can be met by electricity since out of 2700 shops or commercial units only 1175 are electrified. Again 1440 thousand hours of lighting should be met by kerosene only since these small shops are neither electrified nor their owners can install SPV or hire the service of diesel fueled generator set.

Table - 2 : Estimated Demand for Lighting in the Shops and Establishments.

Number of Points	Number of units	Hour /day	Days/yr	Total '000 hr
1	900	4	300	1080
2	900	4	300	2160
4	500	4	300	2400
10	132	8	300	4956
	268	12	300	9468
50	1	24	365	438
	17	4	200	680
			Total	21182

In this sector, cooking is also an important task posing demand. There are 14 hotels and 17 hostels which use energy for meeting their cooking need for 350 days and 200 days respectively. BPHC and other health facility centres need energy for preparing hot water, operating x-ray machines etc. The Block has also a Block Veterinary Service Centre which requires energy for lighting, diet making etc. Hotels can use firewood, LPG, diesel or coal while hostels use only firewood or coal. The hostels use coal and firewood in the ratio of 4.5: 1. Besides these, the sweet shops and tea stalls also consume commercial energy for 350 days per year. Tea stalls usually use kerosene or firewood while sweet shops are using diesel, LPG, firewood or coal in different proportions.

Method of Solution

The multi objective linear sets of relations shown in (1) to (3) can be solved for each of individual objectives O_1 ,O_2, O_3 subject to the set of constraints shown in (4) to (8) and let X^l, X^2 x^3 represent the set of solutions respectively. Since all the three are minimisation type of objective functions, so

$$U_t = \text{Min}\,(O_t\,(x^t)) \text{ and}$$
$$L_t = \text{Max}\,(O_t\,(x^1), O_t\,(x^2), O_t\,(x^3)) \qquad \forall\, t$$

Where U_t and L_t indicate most and least acceptable values for t^{th} objective respectively.

Then μ_t the membership function of t^{th} objective is defined by

$$\mu_t = 0, \qquad \text{when } O_t \geq L_t$$
$$=(L_t - O_t)/(L_t - U_t), \qquad U_t \leq O_t \leq L_t$$
$$= 1, \qquad O_t \leq U_t$$

Therefore three more constraints corresponding to 3 objective functions have been formed on the basis of aspiration levels which are calculated from the above individual solutions.

Now a dummy variable A is introduced for fuzzy optimization such that $\lambda \leq \mu_t\,, \ \forall t$

Then Fuzzy Linear Programming (FLP) becomes

$$
\begin{aligned}
&\text{Maximize } \lambda \\
&\text{Subject to:} \\
&O_t + (L_t - U_t)\,\lambda \le L_t, \\
&\lambda \ge 0
\end{aligned}
$$

And all other constraints used in individual objectives including non-negativity of decision variables.

Then applying MOFLP technique the most compromised solution of all these 3 objectives has been achieved.

Results and Discussions

All shops and establishments need lighting energy. According to their size, their demand is catagorised but for all these catagories kerosene, electricity, Spy or diesel (generator set) are the options for lighting. Table - 3 shows the results of this model.

Table- 3: Energy Allocation for Industries, Shops & Establishments Sector

Task		Obj -1		Obj -2		Obj -3		Fuzzy	
		Source (unit)	Quantity	Source (unit)	Quantity	Source (unit)	Quantity	Source (unit)	Quantity
Lighting		Kerosene ('000lt)	47.1	Kerosene ('000lt)	29.5	Kerosene ('000lt)	29.5	Kerosene ('000lt)	29.5
		Electricity (MWh)	204.2	Electricity (MWh)	17.6	Electricity (MWh)	204.2	Electricity (MWh)	170.8
				Spy (MWh)	197.4	SPY (MWh)	10.7	SPY (MWh)	44.2
Cooking	Hotel	Firewood (ton)	132.3	Firewood (ton)	132.3	LPG (ton)	250.4	LPG (ton)	250.4
	Hostel	Firewood (ton)	183.6	Firewood (ton)	183.6	Coal (ton) Firewood (ton)	122.4 27.2	Firewood (ton)	183.6
	Tea Stall	Firewood (ton)	505.3	Firewood (ton)	505.3	Kerosene ('000lt)	144.4	Firewood (ton)	505.3
	Sweet Shop	Firewood (ton)	891.8	Firewood (ton)	891.8	LPG (ton)	171.1	LPG (ton) Firewood (ton)	123.3 248.9

Results of objective-1(i.e.for minimization of total cost) reveals the maximum possible use of electricity and indicates that the rest of the demand will be fulfilled by kerosene. Objective-2 (i.e., to minimize non-local sources) implies maximum use of local sources to meet the demand. So it reflects the maximum possible use of Spy followed by

kerosene and electricity. To increase overall efficiency i.e. to achieve the optimum result of objective - 3, electricity is used to its maximum extent and kerosene is used as less as possible. The use of kerosene may be limited for satisfying the demands of those task for which there exist no other option. SPY is used to meet the rest of the demand.

Fuzzy solution compromises the above combinations to get an intermediate value for each objective. And for this also, kerosene is used as little as possible and the rest is met by electricity (170.8 MWh) and SPY (44.2 MWh).

Besides lighting end use, some shops and establishments need 63184.93GJ energy for cooking task. Hotels, hostels, sweets shops and tea stalls prefer fire wood and need as much as 34917.5GJ energy for cooking.

For minimization of non-local sources sweets shops, tea stalls, hotels and hostels will also prefer only firewood.To get overall efficiency, hotels look for LPG whereas hostels prefer coal for their cooking end use. Tea stalls may use kerosene whereas sweets shops can fulfill their demand by LPG.

The MOFLP model gives the compromised result of all these combinations. Hotels can use LPG for their cooking whereas hostels and tea stalls may use firewood for the same task,; Sweet shops can use both the sources. In the Block there is 110 sweets shops of which 72 % prefer LPG and rest look for firewood to get a compromised result.

Conclusion

It is observed from this model that lighting is the major end use of this sector and kerosene is economically the most viable source for lighting. Some small shops have no other option against this but electricity is the most viable source in terms of comparative economic and qualitative outcome. Electrified shops or establishments never think of any other source. Since the availability of electricity is irregular, diesel fueled generator sets are presently installed at almost all the market places. From this model, it is seen that diesel fueled generator sets are not at all viable in respect of any goal like cost minimisation, overall efficiency increase etc. Spy may substitute this system which is pollution free, eco-friendly and renewable in nature. Now-a-days some people are providing lighting points to the shops through diesel fueled generator sets. Spy system has the potential to replace the former ones. Government may promote them through issuing soft loan etc. Such replacement can help in saving diesel, protect environment and generate employment opportunities in rural areas.

The overall result indicates preference for electric connections and suggests wide use of LPG. SPY system needs to be introduced.

Acknowledgement

The author is thankful to Department of Science and Technology (DST), Govt. of India for their financial support under SERC FAST Track scheme for the work.

Reference

1. Chedid R, Mezha T and Jarronche C (1999), "A Fuzzy Programming Approach to Energy Resource Allocation ", *International Journal of Energy Research, Vol.23,* ppJ03-317.
2. Chetty K. M. and Subramanian. O. K. (1988), "Rural Energy Consumption Patterns with Multiple Objectives",*International Journal of Energy Research,* Vol. 12. pp. 561-567.
3. Jana Chinmoy and Chattopadhyay R N (2001), "Planning for Rural Energy Allocation in the Cooking Sector-A Multiple Objective Fuzzy Linear Programming Approach", Indian Journal of Regional Science, VoL-XXXIII, No.-2, Pp-74-82.
4. Jana Chinmoy and Chattopadhyay R N(2004),"Block Level Energy Planning for Domestic Lighting - A Multi Objective Fuzzy Linear Programming Approach ", Energy, Vol. 29, No,ll, Pp-1819-1829.
5. Joshi.B, Bhatia.T.S, Bansal.N.K and Grover P.O. (1991), "Decentralized Energy Planning Model for Optimum Resources Allocation with a Case Study of the Domestic Sector of Rurals in Nepal", *International Journal of Energy Research,* Vo1.15, pp. 7178
6. Narasimhan R (1980), "Goal Programming in a Fuzzy Environment", *Decision Sciences,* Vol.11, pp.325-336.
7. Zimmerman H J (1996)," *Fuzzy Set Theory and its Applications ".* Allied Publishers Limited.