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Adoptability of Sustainable Energy in Rural India

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Abstract*: Access to energy is an important determinant for social and economic well-being of any society. In recent time though India is witnessing a rapid development country, but access to energy, particularly in rural part of India has still remained an unsolved development agenda. Reports show that large sections of population living in rural India and urban slum still do not have access to modern energy services. Therefore, this paper identifies and investigates the factors responsible for adoptability (or lack of it) of sustainable energy in rural India through extensive literature review. Further, a framework is developed in this study using Fuzzy-AHP approach to analyse the factors impeding and facilitating the state of adoptability of sustainable energy technologies in rural India. The results of the study reveals that, electrical connectivity (EC), income consistency(IC), average family Size (AFS), proximity to cities(PC), ecological conditions(EC) and sanitation(SA) are the key attribute in determining the level of adoptability rather than the actual knowledge or awareness. Moreover, this research work will be useful for energy planners, academicians and NGOs working in the field for developing strategies for successful implementation of sustainable energy supply programs particularly in rural area.

***Keywords* : Affordability, Availability Energy, AHP, Energy access, Sustainability**

I. INTRODUCTION

There is a rapid change in lifestyle of people of cities in India. But at the same time, people in rural part of India desire to change their lifestyle. Though the village lifestyle seems to be pleasurable, the real challenge existing in this is lack of amenities like convenient use of gas ,electricity etc which makes the urban life more easier. Definitely it has an impact on the basic needs of human life. These most needed source of energy will There are lot of people do not have electricity till now [1]. In this study, we examine the factors which prevents penetration of energy services in rural India and also determine the relative weight of each of these factors. Fuzzy-AHP approach is applied for analysis to gain insight into the problem. The results obtained through this analysis is expected to be useful to the energy planners, academicians and civil society for formulating a sustainable energy plan for rural India. [2] examined critical characteristics of learning framework in the renewable energy industry.

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They investigated different organization forms for knowledge management at different levels of supply chain and proposed suitable organizational forms under different situation for sustainable competitive. [3] have made an attempt to identify the major barriers to the rate of adoption of renewable and green technologies. Context. [4] proposed a new generic process model embedding the Framework of Strategic Sustainable Development. [5] presented a review in theoretical basis for community behaviour as a catalyst for energy behaviour change; examining contrasting view points of the definition of commuting energy. [6] analysed the renewable energy sector in European Union. [7] presented a generic model to evaluate manufacturing plant sustainability using Fuzzy -AHP approach. [8] developed an integrated fuzzy AHP-VIKOR approach-based framework for sustainable global supplier selection that takes sustainability risks from sub-suppliers.

II. PROBLEM FRAMEWORK

There are several factors that influence the state of energy-access, particularly in rural India. These factors very across the country because of cultural diversity, and demographic composition and geographical attributes, but some critical factors which remain universal plays a decisive role.The critical parameters were identified through the literature survey, and interaction with experts from the field of energy planning, energy management, rural development, social welfare, and environment management. The parameters so identified and its attributes are discussed in greater detail, and the frame work of the problem is shown in Figure 1.

A. Availability.

The service which is to be acceded and used must be availability in the first place. In rural area energy is primarily required for cooking, agriculture, food processing, irrigation and animal husbandry. Therefore, electricity, cooking fuel, bio-fuel and other forms of renewable energy source forms the energy portfolio if rural India. The status of availability is expressed as a discrete variable based on the public response. The sub-criteria which describes the this factor are Electrical Connectivity (EC), Cooking gas (CG), renewable energy (RE) and scarcity of Biofuel (SB).

B. Affordability.

For any service, once it is available, it must be affordable so that it can be accessed. Affordability is indicative of the purchasing ability of the household to buy a particular service, and to adapt new life style. Affordability therefore plays an important role in making a choice for adopting a mode of energy supply.

The sub-ingredients of affordability are average income(AI), dependence on agriculture(DA), income consitency (IC) and average family size(AFS).

C. Reliability.

Reliability is defined as the measure of ability of the system to meet the customer demand continuously as and when demanded. The factors belong to this reliability are electric distribution infrastructure(EDI), communication(CM), skilled manpower(SM) and proximity to cities(PC)

D. Acceptability.

The Acceptability is defined as the extent to which there is willingness of the people to internalise the products or services. This is largely driven by the level of awareness and perception about a product and service. The sub-ingredients are level of awareness(LA), cultural bias(CB), convince of use(CU) and benefit perception(BP).

E. Environmental Condition.

Over the centuries environmental conditions have shaped up the life style of the society. The environmental attributes determines what surrounds us and what is produced around us, and therefore, human behaviour is always modulated in a manner that ensures co-existence of man and nature. Four ingredients are discussed in this context are ecological condition (EC), political commitment (PC), climate condition (CC) and sanitation (SA).

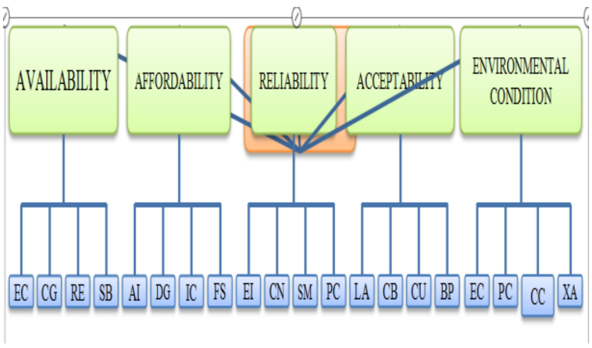

Fig. 1: Framework of the problem

III. PROPOSED APPROACH

A. Methodology

In this work, a Fuzzy-AHP is applied and detailed are described as follows.

The Algebraic functions on triangular fuzzy numbers follow the same mathematical rule. The m extent analysis values for each criteria are denoted as follows (Tiwari et al, 2008).

$N_{oi}^{1}, N_{oi}^{2}, \ldots, N_{oi}^{m}$ where i = 1,2, ..., n

N_{oi}^{j} : The triangular fuzzy member (j=1,2,..,3)

N_{oi}^{m} : The value of extent analysis of ith object for mth goal

The value of fuzzy synthetic extent with respect to ith object is defined as

$$K_i = \sum_{j=1}^{m} N_{oi}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]^{-1}$$

The value $\sum_{j=1}^{m} N_{oi}^{j}$ can be found by performing fuzzy addition operation of m extent analysis values from a particular matrix such that

$$\sum_{j=1}^{m} N_{oi}^{j} = \left(\sum_{j=1}^{m} n1j, \sum_{j=1}^{m} n2j, \sum_{j=1}^{m} n3j \right)$$

The value of $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]$ can be obtained by performing the fuzzy addition of N_{oi}^{j} (j=1,2,..,n) such that

$$\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} = \left(\sum_{j=1}^{m} n1j, \sum_{j=1}^{m} n2j, \sum_{j=1}^{m} n3j \right)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} N_{oi}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} n_{3i}}, \frac{1}{\sum_{i=1}^{n} n_{2i}}, \frac{1}{\sum_{i=1}^{n} n_{1i}} \right)$$

The degree of possibility of $N_1 = (n_{11}, n_{12}, n_{13}) \geq N_2 = (n_{21}, n_{22}, n_{23})$ is defined as the $V(N_1 \geq N_2) = \sup_{x \geq y} [\min(\mu N_1(x), \mu N_2(x))]$ When a pair(x,y) exist such that $x \geq y$ and $\mu N_1(x)$ = $\mu N_2(x)$ =1, then we have $V(N_1 \geq N_2) = 1$. The N1 and N2 are the convex fuzzy numbers so

$$V(N_1 \geq N_2) = 1 \quad if \; n_{11} \geq n_{21} \; V(N_1 \geq N_2) = hgt(N_1 \cap N_2) = \mu N_1(d)$$

Where d is the ordinate point of the highest intersection point D between μN_1 and μN_2 .When $N_1 = (n_{11}, n_{12}, n_{13}) \, and \, N_2 = (n_{21}, n_{22}, n_{23})$, then ordinate of D is calculated by

$$V(N_1 \geq N_2) = hgt(N_1 \cap N_2) = \frac{n_{11} - n_{23}}{(n_{22} - n_{23}) - (n_{12} - n_{11})}$$

For the comparison of N1 and N2, both values of $V(N_1 \geq N_2)$ and $V(N_2 \geq N_1)$ are required.

The degree of possibility for a convex fuzzy number to be greater than k convex fuzzy number N_i (i=1,2,..k) can be defined as

$$V(N \geq N_1, N_2, \ldots, N_k) = V[(N \geq N_1) \, and \, (N \geq N_2) \, and \ldots and \, (N \geq N_k)]$$

$$= \min V(N \geq N_1), i = 1, 2, \ldots, k$$

$$if \; m(P_i) = \min V(K_i \geq K_k)$$

For k=1,2,3...k, $k \neq i$, then the weighted vector is given by $W_P = (m(P_1), m(P_1), \ldots, m(P_n))^T \; where \; P_i (i = 1, 2, 3, .., n)$ are n elements.

After normalizing Wp, we get the normalized weight vectors $W = (w(P_1), w(P_2), \ldots, w(P_n))^T$

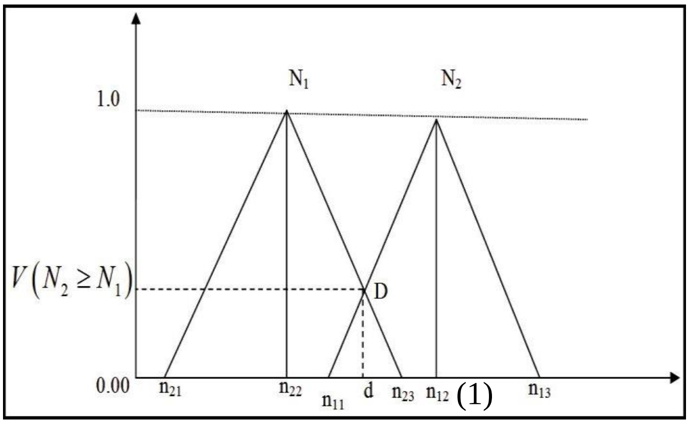

Fig. 2: Intersection Between N_1 and N_2.

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B. The proposed AHP model

Step1: First we consider all construct, sub construct and sub-sub-sub construct for Sustainable Selection.
Step 2: The weights are calculated by using Fuzzy Mapping function.
Step 3: The weight are calculated on each pairwise matrix.
Step 4: Global priority are calculated
Step-5: Calculation Of Overall weight
The overall weight is calculated by the product of the global weight of critical factor and the weight of sub-factor which are belong to the main parameter. Based on the overall weight of sub-parameters, the ranking is done to adapt the critical sub-parameters [9].
Overall weight = global weight*weight of sub-parameters

IV. RESULT AND DISCUSSION

The rating of the critical parameters and sub-parameters are done by experts from the field of energy planning, energy management, rural development, social welfare, and environment management.
Five critical factors such as Availability, Affordability, Reliability, Acceptability and Environmental Conditions are checked for hierarchy. The weights given by the experts are shown in the following table:

Table 1: Pair-wise matrix of Availability

	EL	CG	RE	SB	w
EL	1,1,1	1.5,2,3	3,4,5	2,3,4	0.5377
CG	.333,.5,.666	1,1,1	.5,.666,1	.285,.333,.4	0.1412
RE	.2,.25,.333	1,1.5,2	1,1,1	1,2,3	0.1707
SB	.25,.333,.5	2.5,3,3.5	.333,.5,1	1,1,1	0.1504

The weights are calculated using Fuzzy Mapping function
F1= (1+1.5+3+2, 1+2+4+3, 1+3+5+4)= (7.5, 10,13)
Similarly,
F2= (2.118, 2.499, 3.066)
F3= (3.2, 4.75, 6.333)
F4= (4.083, 4.833, 6)
K1= (7.5,10,13) $(16.901, 22.082, 28.399)^{-1}$ =(0.2641,0.4529,0.7692)
Where 16.901 = 7.5+2.118+3.2+4.083
Similarly,
K2= (0.0746, 0.1132, 0.1814)
K3= (0.1127, 0.2151, 0.3747)
K4= (0.1438, 0.2189, 0.3550)
Here we see that $V(K2 \geq K1) = 1$ if n11> n22, then we get the final value of weights after normalizing. Normalizing these value, we get the final result as(0.5377, 0.1412, 0.1707, 0.1504). Similarly, the normalizing weight of different criteria are calculated (Table 2,3,4,5,6).
The overall weight of each criteria is calculated and show in Table7 and Figure 3.

Table 2:Pair-wise matrix of Affordability

	AI	DG	IC	FS	w
AI	1,1,1	1,2,3	1.5,2,3	.2,.333,.5	0.2162
DG	.333,.5,1	1,1,1	.2,.25,.333	1,2,3	0.1046
IC	.333,.5,.666	3,4,5	1,1,1	2.5,3,3.5	0.3578
FS	2,3,5	.333,.5,1	2.5,3,3.5	1,1,1	0.3214

Table 3: Pair-wise matrix of Reliability

	EI	CN	SM	PC	w
EI	1,1,1	2,3,4	.142,.166,.2	5.6,7,8.4	0.4018
CN	.25,.333,.5	1,1,1	3,4,5	0.2,.25,.285	0.0596
SM	5,6,7	.2,.25,.333	1,1,1	.1666,.2,.25	0.1848
PC	.119,.142,.178	3.5,4,5	4,5,6	1,1,1	0.3538

Table 4:Pair-wise matrix of Acceptability

	LA	CB	CU	BP	w
LA	1,1,1	.142,.166,.208	.166,.2,.25	6.4,8,9	0.21
CB	4.8,6,7	1,1,1	4,5,6	.111,.25,.156	0.2643
CU	4,5,6	.166,.2,.25	1,1,1	4.8,6,7	0.2643
BP	.111,.25,.156	6.4,8,9	.142, .166,208	1,1,1	0.2614

Table 5: Pair-wise matrix of Environment

	EC	PC	CC	SA	w
EC	1,1,1	.25,.333,.5	4,5,6	5.5,6,7	0.4946
PC	2,3,4	1,1,1	.2,.333,.5	.142,.166,.2	0.0375
CC	.166,.2,.25	2,3,5	1,1,1	.2,.25,.333	0.041
SA	.142,.166,.181	5,6,7	3,4,5	1,1,1	0.4269

Table 6: Global weight

	Availa bility	Afford ability	Reliabil ity	Accept ability	Environ mental
Availab ility	1,1,1	2,3,5	4.5,5,6	.2,.25,.285	.25,.333,.4
Afforda bility	.2,.333,.5	1,1,1	.125,.142,.178	.166,.2,.25	.142,.166,.2
Reliabil ity	.166,.2,.222	5.6,7,8	1,1,1	5.6,7,8	.2,.25,.285
Accepta bility	3.5,4,5	4,5,6	.125,.142,.178	1,1,1	2,3,4
Environ mental	2.5,3,4	5,6,7	3.5,4,5	.25,.333,.5	1,1,1

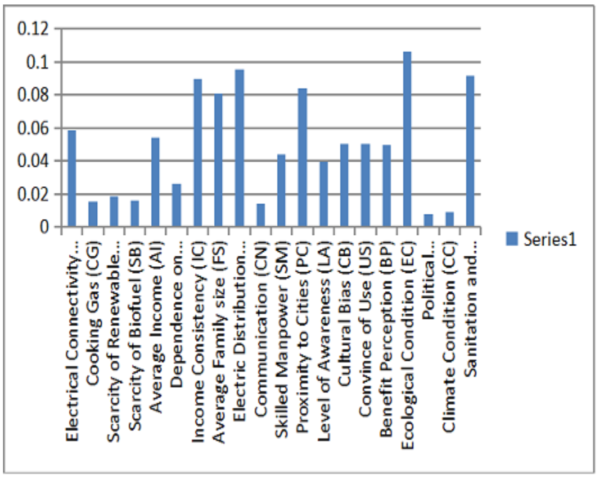

Fig. 3 : Overall weight of sub-factors

Table 7: Overall weight

Critical factors	Global weight	Sub parameters	Weight	Overall weight
	0.1086	Electrical Connectivity **(EL)**	0.5377	0.0584
		Cooking Gas **(CG)**	0.1412	0.0154
		Scarcity of Renewable Energy **(RE)**	0.1707	0.0185
AVAILABILITY		Scarcity of Biofuel **(SB)**	0.1504	0.0163
	0.2504	Average Income **(AI)**	0.2162	0.0541
		Dependence on Agriculture **(DG)**	0.1046	0.0262
AFFORDABILITY		Income Consistency **(IC)**	0.3578	0.0896
		Average Family size **(FS)**	0.3214	0.0805
	0.237	Electric Distribution Infrastructure **(EI)**	0.4018	0.0952
		Communication (**CN**)	0.0596	0.0141
		Skilled Manpower **(SM)**	0.1848	0.0438
RELIABILITY		Proximity to Cities **(PC)**	0.3538	0.0839
	0.1893	Level of Awareness **(LA)**	0.21	0.0398
		Cultural Bias **(CB)**	0.2643	0.05
		Convince of Use **(US)**	0.2643	0.05
ACCEPTABILITY		Benefit Perception **(BP)**	0.2614	0.0495
	0.2147	Ecological Condition **(EC)**	0.4946	0.1062
		Political Commitment**(PI)**	0.0375	0.008
ENVIRONMENTAL		Climate Condition **(CC)**	0.041	0.0088
CONDITION		Sanitation and Cleanliness **(SC)**	0.4269	0.0917

V. CONCLUSION

It is observed that that large sections of population living in rural India and urban slum still do not have access to modern energy services. There are several factors that influence the state of energy-access, particularly in rural India. Therefore, this research makes an attempt to identify and evaluate the factors influencing the provision of energy services in rural India. In this paper, Fuzzy-AHP remains the principal approach for the evaluation process.

The present study is conducted by obtaining expert opinions on the subject matter from the professionals working in the area of energy planning, administrators, rural development professionals, NGOs and others.

This study identifies the five main factors such as availability, affordability, reliability, acceptability, and environmental conditions which influence the access of sustainable energy in rural India. Further, a framework is developed (Figure 1) which categorizes the main factors into sub-factors. A total of 20 sub-factors-four factors for each main factor-are determined. The results of Fuzzy AHP approach indicates that, electrical connectivity (EC), income consistency (IC), average family size (AFS), proximity to cities (PC), ecological conditions (EC) and sanitation (SA) are the key attribute in determining the level of adoptability rather than the actual knowledge or awareness. In such a circumstance information asymmetry can play an important role in choosing appropriate mode of energy service. Therefore, it is suggested that attempts by the Government to spread knowledge and awareness must be intensified. The study further indicates that, in rural area the reliance on biomass for meeting the energy need is still predominant. Use of biomass is no doubt a sustainable method of energy use, however, care must be taken to ensure that, the consumption does not exceed the carrying capacity, since over-consumption may ultimately lead to environmental degradation.

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