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AN OVERVIEW OF ADOPTION OF ENERGY EFFICIENT TECHNOLOGIES IN INDIAN URBAN HOUSEHOLDS

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ABSTRACT

Household energy conservation has been a topic of interest within applied social and environmental psychology research for a number of decades. Households constitute an important target group since they are also major contributors to the emission of greenhouse gases and hence global warming. At present, the share of direct energy use of Indian households is about 40% of the total direct commercial and noncommercial indigenous energy use. If, in addition, one takes into account the indirect or embodied energy in all goods and services purchased by households, about 70% of the total energy use of the economy can be associated with the household sector. The experience of the last 30 years shows that the rise of gross energy demand has by far exceeded the growth rates of population. In this backdrop and with the growing share of India in global energy use and CO_2 emissions, it is important to analyze the factors that are contributing to this scenario. This paper attempts to do the same by using the results of a pilot study undertaken in order to validate the approach to be used for a full blown study of the usage of energy efficient technologies in the households of urban India.

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INTRODUCTION

The energy use in the residential sector is an important area for campaigns to conserve energy. Energy saving in the home creates benefits for the household in the form of lower energy bills, and for the community at large in the form of lower imports (Vaanraaij and Verhallen, 1983). Households constitute an important target group as they are major contributors to the emission of greenhouse gases and consequently, to global warming. In 1970s, energy research was driven by the raising concern about a possible depletion of fossil fuels, but today environmental problems like global warming, and threats to biodiversity are of primary concern.

There is a multiplicity of reasons why the study of household consumption patterns and energy requirements is of immense importance especially for a large and developing country like India. Households are a major consumer of energy and contribute, to a large extent, to the total energy use of the nation. Currently, the share of direct energy use of households in India is about 40% (Shonali and Daniel, 2002) and it goes up to 70%, if one takes into account the indirect or embodied energy in all goods and services purchased by households (Shonali, 2004). Various social and environmental psychology studies have embarked on issues related to household energy use. Some focus on effectiveness of intervention strategies aiming to change energy-related behaviors, while the others aim at identifying underlying determinants of energy use (Wokje *et al.,* 2005)**.** Do consumers behave rationally in making decisions regarding energy use and energy efficiency? Do observed choices reflect an optimal balance between the costs and benefits of energy-efficient technologies? Do people use economic criteria when purchasing appliances or automobiles? Do households minimize the present-value costs of obtaining energy services? Debates over these key questions have continued unabated for two decades, becoming more intense in recent years due to growing concerns of environmental impacts of energy use (Alan and Richard, 1994). In India, 1990s saw energy use growing at 5% every year, while the Indian population increased by less than 2%. The growth in demand has even offset all the savings achieved by energy efficiency increases. Given this scenario and the growing share of India in global energy use and CO_2 emissions, it is important to analyze the factors that are contributing to this (Reddy and Balachandra, 2004).

An attempt has been made in this paper to present the various factors which seem to be influencing the choice of energy efficient technologies in Indian urban households. These factors have been analyzed in the backdrop of a pilot study concluded recently. The paper is divided into three sections. The first section discuses the relevance of the study followed by a detailed literature review. In the second section a discussion of questionnaire design, income stratification, scale selection and other intricacies of the research methodology is presented. The third section contains the analysis of results and conclusions.

The primary purpose of household energy consumption and conservation research is to understand the factors influencing energy-consuming behaviors. Although the purpose is clear, the task of understanding energy-consuming behaviors presents substantial complexities. The complexities involve determining both the factors that influence energy-consuming behaviors and the nature of their influence (Brent Ritchie*, et al.,* 1981). The energy usage of a household is influenced by energy related behaviors viz. purchase, usage and maintenance related behaviors (Vaanraaij and Verhallen, 1983). Purchase-related behavior deals with the relative importance and usage of the energy attribute of the products, usage-related behavior refers to the day-to-day usage of appliances in the home and the home itself and maintenance-related behavior refers to, the behavior to maintain the in-home appliances. A number of personal factors may also influence energy-related attitudes and behaviors. Household income, educational level and employment are also related to energy use (Vaanraaij and Verhallen, 1983).

Climatic conditions, house/product/vehicle characteristics, household demographics and attitudinal variables are also mentioned in the literature as influencing the household energy use (Brent Ritchie *et al.,* 1981).

Increase in the energy use of households is also attributed to TEDIC factors (Wokje *et al.,* 2005): Technological developments (*e.g.* energy-intensive appliances), Economic growth (*e.g.* increase of household incomes), Demographic factors (*e.g.* population growth), Institutional factors (*e.g.* governmental policies) and Cultural developments (*e.g.* emancipation, increasing mobility of women).

The behavioral literature quotes the following empirical regularities each of which is thought to promote the over utilization of energy (Alan and Richard, 1994):

- Use of high implicit discount rates in evaluating energy-efficiency investments.
- Use of incorrect units in calculating energy consumption and related costs, resulting in over consumption relative to what would result from technically correct computations.
- Salience effects, whereby consumers attach excessive weight to factors that are psychologically vivid or easily observed — for example, turning down the lights in an effort to reduce energy bills when such action will generate negligible cost savings.
- Incorrect use of technology — for example, failure to understand the concept of thermostatic control so that users set air conditioners too "high" relative to the levels required to assure sustained comfort.

In his book "Energy and Social issues", (Reddy, 2000) has discussed elaborately the positive and negative impacts of urbanization on energy usage. Urbanization reflects more than demographic change. It exerts both direct and indirect advantages in the struggle towards global sustainability and human development. The origins of many global environmental problems related to air and water pollution are located in cities. Unsustainable consumption and production patterns are also a feature of cities. But it is also in cities that one can find potential solutions, because they have several positive features. Birth rates are three to four times lower in urban areas than in rural areas, thereby reducing environmental pressures from population growth. Cities provide greater accessibility to education, services, and training. Because of their concentrated form and efficiencies of scale, cities offer major opportunities to reduce energy demand and minimize pressures on surrounding land and natural resources.

The key determinants of technology choice generally considered by energy modeling tools are capital and operating costs (Lena *et al.,* 2009). Due to high investment requirements, capital costs become a key barrier to investment in energy-efficient technologies. There is compelling evidence that consumers often lack knowledge regarding costs and benefits related to energy efficiency. The decision making in the choice of energy efficient technologies is further compounded if one examines how the consumption characteristics of public and the private, and necessity and luxury, combine to create different symbolic properties as shown in Fig. 1 (Solomon, 1996).

MATERIALS AND METHODS

Questionnaire design

Basically a questionnaire must serve two functions: it must translate research objectives into specific questions the respondent can answer, and it must motivate the respondent to cooperate with the survey and to furnish the information correctly. It is crucial to remember that the questionnaire can also be the source of many errors in a survey. These errors can be summarized under the following headings (Harper *et al.,* 1985) :

Memory: the respondent can't remember or remembers incorrectly.

Motivation: the respondent may be motivated to report incorrectly to provide a better image of him/her.

Communication: the respondent may not understand accurately what he/she is asked.

Knowledge: the respondent simply may not know the answer.

Keeping in mind the above facts, after extensive literature survey and in depth discussions with experts, a list of five important factors influencing the decision making process in choosing energy efficient technologies in the context of Indian urban households were selected. These factors are: Demographic and Economic background, Possession and Awareness of energy efficient technologies, Personal and Behavioral factors, Financial factors and Government policies. Under each factor, several variables were considered amounting to a total of thirty two variables. After several rounds of reviews and consultations with the experts, the final draft of the questionnaire was prepared for administering to the participants.

Measurement scale selection

Because of the nature of information being collected, it was decided to use Likert scale for measurement. The intensity of response obtained is considered to be more discriminating and reliable with this scale. For ease of analysis a score of five to one was selected for each variable (five being the most favorable and one the least). Further, it also was decided to obtain the responses by personal interview with the households.

Income stratification and sample selection

There are two popular sources of income data in India viz. 1) NCAER's MISH (National Council of Applied Economic Research's Market Information Survey of Households) survey and 2) ORG-MARG's IRS survey (ORG-MARG is an international marketing research institute) (Mythili, 2008). For this research survey, it was decided to use the expenditure data and ownership of assets data to arrive at the income classes. According to NSS (National Sample Survey) expenditure data (NSSO, 2008): 12% of the households have MPCE (Monthly Per Capita Expenditure) of Rs. 1380-1880 (House Hold Expenditure (HHE) Rs. 5520-7520, assuming an average of 4 persons per household) and were treated as middle income group households, 7.5 percent of the households have MPCE of Rs. 1880-2540 (HHE - Rs. 7520-10160) and they were treated as upper middle income group and 9.6 percent of the households have MPCE of Rs. 2540 and above (HHE - Rs. 10160 and above), which were treated as high income group households.

A sample of thirty households was chosen for the pilot study. With the target population being top thirty percent, the corresponding figures for survey of thirty households worked out to be, twelve from the middle

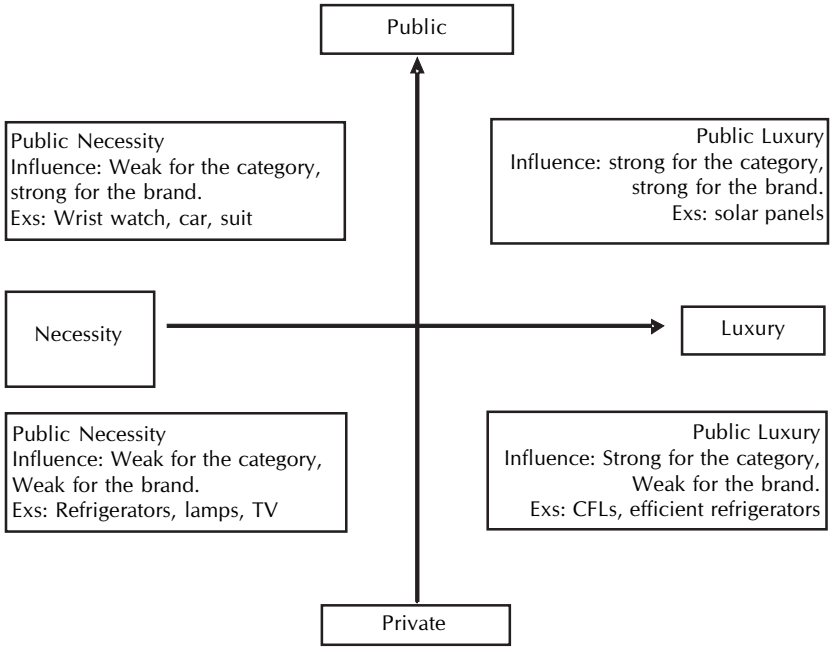

Figure 1: Influence of reference groups (friends, colleagues etc) in purchasing generic categories and products (Adopted from Solomon, 1996)

Table 1: Frequency Table

S. N.	Factor	Frequencies
1	Ownership of energy consuming assets	More than thirty - 50%
2	Awareness about energy efficient technologies	Extremely poor - 40%, Below average - 30%.
3	Number of energy efficient technologies owned by the household	Very little - 36.7%, Somewhat - 53.3%.
4	Degree of satisfaction derived	Largely - 46.7%; To a great extent - 36.7%
5	Awareness about general environmental issues	Very little - 40%Somewhat - 36.7%
6	Awareness about some generalfacts about energy consumption	Somewhat - 56.7%Largely - 33.3%
7	Concern for environment	Good - 50%; Very good - 33.3%
8	Attitude towards change	Agree - 43.3%; Strongly agree - 53.3%
9	Willingness to invest in energy efficient devices	Agree - 36.7%Strongly agree - 50%
10	Willingness to adopt energy efficient methods	Agree - 40%Strongly agree - 60%
11	Income factor	Strongly agree - 63.3%
12	Cost savings	Good - 30%; Significant - 36.7%
13	Purchase cost	Important - 26.7%; Unimportant - 36.7%
14	Maintenance cost	Very little - 73.3%
15	Government subsidies	Strongly agree - 33.3%; Agree - 33.3%
16	Government regulations	Strongly agree - 56.7%
17	Government incentives	Very little - 53.3%
18	Government efforts	Not at all - 23.3%; Very little - 46.7%
19	Product information	Strongly agree - 60%
20	Adequacy of information	Very little - 46.7%; Somewhat - 23.3%
21	Risk coverage	Agree - 30%; Disagree - 36.7%

income group, eight from the upper middle income group and ten from the high income group. The households were selected randomly from different localities within the corporation limits of the Mysore city.

Establishing validity and reliability of the questionnaire

Questionnaires as measuring instruments must be valid and reliable, if they are to produce useful measurements. Validity indicates the degree to which an instrument measures what it is supposed to measure. Validity can be determined by using a panel of experts who shall judge how well the measuring instrument meets the standards (Kothari, 2007). This method was used to validate the questionnaire in the present study (A panel of five experts was used). The reliability of a measure indicates the stability and consistency with which the instrument measures the concept and helps to assess the 'goodness' of a measure. Cronbach's alpha is a reliability coefficient that reflects how well the items in a set are positively correlated to one another (Krishnaswamy *et al.,* 2006). The closer the Cronbach's alpha is to unity, the higher is the internal consistency or reliability. After completing the pilot study, a reliability test was run on the obtained data using SPSS software. This resulted in a Cronbach's alpha value of 0.726. It may be noted here that as the sample size increases, the value of Cronbach's alpha is likely to improve further (SPSS Inc, 1990). As the sample size for the pilot study was only 30, a Cronbach's alpha value of 0.726 was considered to be satisfactory.

RESULTS AND DISCUSSION

The purpose of a pilot study is to validate the questionnaire and the approach used for the study. Perhaps a simple way of looking at the data obtained by the pilot study is to form a frequency Table. The result of the frequency analysis carried out using SPSS software is presented in Table 1. From the household energy consumption point of view, the major highlights of this frequency analysis are discussed briefly here. 50%

Table 2: Cross tabulation results

S.N	Cross tabulation	Chi-square significance	Correlation coefficient
1.	Annual income with		
	Ownership of energy consuming assets	0.033	0.446
	Income factor	0.057	-0.247
	Government regulations	0.047	-0.224
2.	Ownership of energy consuming assets with		
	Monthly expenditure	0.094	0.428
	Annual savings	0.002	0.355
	No. of energy efficient technologies owned	0.050	0.583
	Degree of satisfaction derived	0.003	0.290
	Awareness about environmental issues	0.086	0.493
	Attitude towards change	0.007	0.359
	Willingness to invest	0.029	0.559
	Willingness to adopt	0.087	0.133
	Cost savings	0.033	0.322
	Government regulations	0.001	-0.439
	Product information	0.028	-0.424
3.	Awareness about energy efficient technologies with		
	Number of energy efficient technologies owned	0.080	0.302
	Awareness about environmental issues	0.015	0.413
	Income factor	0.063	0.201
4.	Number of energy efficient technologies owned with		
	Degree of satisfaction	0.000	0.428
	Awareness about environmental issues	0.001	0.678
	Liking towards technology	0.043	0.116
	Government incentives	0.056	0.002
5.	Degree of satisfaction derived with		
	Willingness to invest	0.048	0.182
	Cost savings	0.040	0.389
6.	Awareness about environmental issues with:		
	Attitude towards change	0.068	0.490
	Government regulations	0.056	-0.217
7.	Awareness abut energy consumption facts with		
	Willingness to adopt	0.054	0.420
8.	Concern for environment with		
	Ego factor	0.090	0.037
	Attitude towards change	0.035	0.335
	Product information	0.007	-0.102
	Risk coverage	0.096	-0.246
9.	Willingness to invest with		
	Willingness to adopt	0.085	0.215
	Purchase cost	0.096	0.537
	Maintenance cost	0.008	0.527
	Government subsidies	0.023	-0.365
	Government regulations	0.002	-0.708
	Product information	0.002	-0.839

of the households have more than 30 energy consuming assets. This confirms the fact that urban population is depending more and more on energy consuming appliances in their day to day life. The awareness about energy efficient technologies and general environmental issues is very poor. This is found to be true in the case of households in developed countries also (Vaanraaij and Verhallen, 1983). Ninety percent of the households own somewhat or very little number of energy efficient devices. Most of these devices are CFLs and solar water heaters. However, most of the households say that they are quite satisfied with the performance of whatever energy efficient technologies they have. Awareness about general facts regarding energy consumption is definitely better amongst the households. There is also genuine concern amongst the households about the environment. Overwhelming majority of the households (96.6%) is willing to change their life styles in order to use energy efficient technologies. When it comes to the investment in energy efficient

technologies, households tend to become bit cautious (50% - strongly agree, 36.7% - agree). All the households interviewed expressed their willingness to adopt to use energy efficient technologies.
The response of the households when they were asked whether they are willing to increase their investment in energy efficient technologies proportionately as their income increases was quite favorable. 63.7% strongly agreed and 16.7% agreed. With the ownership of energy efficient technologies being poor, the question of cost savings on account of energy efficient technologies (as is maintenance cost), is not so relevant at this stage. With regard to the purchase cost of an energy efficient device, 46.7% of the households feel that it is not important, while almost equal number (53.3%), feel that it is important. Majority of the households want government subsidies (66.6%) and insist on government regulations (73.4%) for the use of energy efficient technologies. 90% of the households are not satisfied with the government incentives and efforts in promoting the use of energy efficient technologies. This supports the fact repeatedly mentioned in the literature (Vaanraaij and Verhallen, 1983), that many of the households hold government as being responsible for energy conservation. There is definitely an agreement amongst majority of the households (90%) about the importance of providing product information to help households make right decisions about energy efficient technologies, while majority of them (80%) are not satisfied with the amount of information that is being provided to them. As far as risk coverage in the form of insurance and others is considered, there is no clear cut agreement amongst the households, with 46.7% agreeing, another 46.7% disagreeing and the rest being undecided.

Another analysis which was carried out on the pilot study data was cross tabulation. The purpose of cross tabulation is to show the relationship (or the lack of it) between two or more variables. Sometimes two variables may appear to be related, but to make sure that the relationship is something more than a random variation a number of tests are available. One of the more commonly used test, is the Chi-square test. One of the advantages of Chi-square test is that, it is suitable for almost any type of data. Statisticians say that when the Chi-square significance value is less than or equal to 0.05, the cross tabulated variables may be considered to be related with one another (SPSS Inc, 1990). It is also true that as the sample size increases, the strength of relationship (as measured by the value of Chi-square significance) also increases. Keeping these facts in mind, it was decided to look at all the relationships between variables cross tabulated, whose Chi-square significance value is less than or equal to 0.1. The Table 2 shows these relationships along with the Chi-square significance value and the correlation coefficients.

Though the tabulations are self explanatory and must be considered cautiously because of the small sample size, it is interesting to look at a few significant relationships that have emerged from this cross tabulation analysis. Annual income is positively correlated with Ownership of energy consuming assets, but negatively correlated with Income factor and Government regulations. This means that households with higher income have more number of energy consuming assets, but they are not willing to invest in energy efficient technologies proportionately with their increase in income. Awareness about energy efficient technologies an important factor in the study, is positively correlated with only three factors. Number of energy efficient technologies owned, apart from Awareness about energy efficient technologies, is also positively correlated with four variables. The degree of satisfaction derived from the existing energy efficient technologies and awareness about environmental issues are significantly correlated with two variables each. Awareness about energy consumption facts is related only with Willingness to adopt. Concern for environment is positively correlated with Ego factor (very weak correlation) and Attitude towards change which is quite understandable. But what is surprising is that, these households also expect product information and insurance coverage for them to adopt energy efficient devices, as there is a negative correlation with them. The next important and interesting relationship which has emerged is with respect to Willingness to invest. This variable is positively correlated with Ownership of energy consuming assets, Monthly expenditure, Degree of satisfaction derived, Attitude towards change, Willingness to adopt, Purchase cost and Maintenance cost. It is also negatively correlated with Government subsidies, Government regulations and product information. This means that, households which are willing to invest in energy efficient devices also expect government subsidies and government regulations for them to adopt energy efficient devices, and also feel that providing product

information will definitely help.

CONCLUSION

This pilot study was conducted with the intention of validating the questionnaire and the approach to be used for the full blown study on the attitude of Indian urban households in the use of energy efficient technologies. Hence the statistical analysis is limited to Frequency distribution and Cross tabulation. The frequency analysis has thrown some light on several issues concerning urban household energy use. Firstly, the urban households use a large number of energy consuming assets, but the ownership of energy efficient devices and the awareness about such devices is very poor. Though the concern about environment is good, Awareness about environmental issues is poor. Households are willing to invest and adopt energy efficient technologies but they want government incentives and subsidies for the same. Most of the households are also not satisfied with the government efforts in this direction and also feel that no proper information about such devices is available. These issues have given some direction for the detailed study to be undertaken and also have lead to some possible changes in the questionnaire design. Some of the relationships which were looked into, under cross tabulation analysis are: the relationship of Annual income, Ownership of energy consuming assets, Awareness about energy efficient technologies, Number of energy efficient technologies owned, The degree of satisfaction derived from the existing energy efficient technologies, Awareness about environmental issues, Awareness about energy consumption facts, Concern for environment and Willingness to invest with the cross tabulated variables. Here, only those relationships where the Chi-square significance value less than or equal to 0.1 have been considered. These relationships along with their correlation coefficients have largely validated the general hypotheses about the variables which were assumed to be influencing the choice of energy efficient technologies in Indian urban households. There have been some exceptions here and there and these exceptions have indicated that some degree of caution is required while carrying out the full blown study.

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