Acute Assessment of Dynamics, Barriers and Resolutions Governing Household Energy Efficiency: Global Review

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***Abstract*—The article presents the views of energy scholars, researchers about household energy efficiency in global sphere. Past and current trends in the field of energy analysis are investigated. The objective of this paper is to provide brief household energy analysis and rather, it reviews current knowledge on energy analysis and identifies factors affecting the energy requirements and energy use patterns among households. The paper also combines the global barriers of household energy efficiency. We have summarized the recommendations of worldwide energy researchers to enhance the energy efficiency. The paper provide research gap, which will be positively useful for techno social researchers. The results of energy education experiments, energy information system seems to be helpful for governments and policy makers. However US, European, Chinese, Japanese research has been able to measure the influence of behavior on household energy consumption, to date Indian research has been unable to do so.**

***Index Terms*—energy awareness, energy conservation, energy efficiency, electricity, household behavior.**

I. Introduction

The literature in the field of energy conservation behavior is extensive and it covers a wide range of subjects and technical disciplines. Household energy use has distinctive features that make it harder to assess and analyse compared to other sectors. For instance, there is range in energy systems at both the household energy demand side and the energy supply side. The energy consumption of households attracts a lot of attention from global social/technical researchers and local authorities within their efforts aimed at overall energy savings and sustainable use. During the last 10–15 years, earth is witnessing a significant upsurge in household energy use due to technological development. At the same time, we are neglecting the problem of depletion of conventional energy resources. Researchers have been exploring various dimensions of household energy use in order to design strategies to provide protected access to recent energy services. However, despite more than three decades of effort, our understanding of household energy use patterns is very limited. Interviews, field works, questionnaire based personal survey, and internet survey, postal survey, and free consultancy are various methodological tools used by global researchers to investigate into the discernment of energy, its significance to populace. We the authors from India take the opportunity to discuss the factors affecting household energy consumption, methods to develop energy conservation pattern all over the globe.

II. Review of Field Works

Zhao Hua Wang and Bin Zhang [1] examined the electricity saving behaviour of 816 randomly selected households using logic regression analysis. The results indicated great potential to reduce unnecessary electricity use from the household perspective focussing on energy efficient utilization and household electricity consumption.

Econometric model [3] given by equation (1) give measure of willingness of residents to save the electricity.

$$\text{LOGIT}(R) = 1/(1+e^{-z}) \quad (1)$$

where, $z=\beta_0+\sum\beta_i x_i$ and R, β_0, β_i, and x_i are the parameters of logit regression model.

Ajzen [2] prepared the framework shown in Fig. 1, based on theory of planned behavior (TPB) of the populace, which may effectively be used to understand

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the behavioural pattern of the households in the context of energy saving.

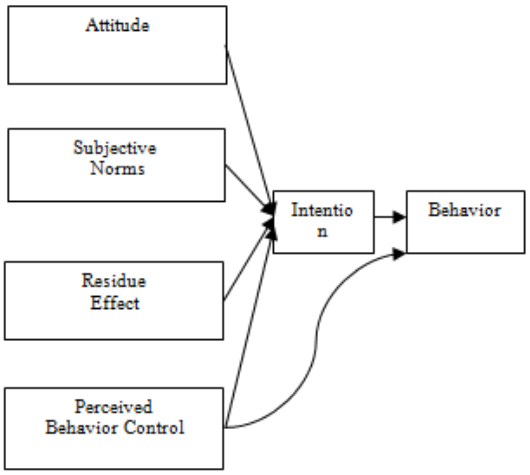

Figure 1. The framework of TPB.

Postal survey of about 1200 households in Sweden tested the hypothesis [4] that, information about available savings measures if presented in a more concrete and specific way is more likely to affect (stated) behaviour than more general information. Kristina Ek [4] assumed that electricity saving behaviour governed by the factors viz. a) Benefits and costs b) Status and c) Information.

Brandon and Lewis [5] combine a qualitative and a quantitative approach in examining the energy consumption in the UK, concentrating on different forms of consumption feedback. They find that this feedback in combination with environmental attitudes had significant impacts on conservation behaviour, while socio-economic factors primarily explained historic consumption patterns. Sardianou [6] inspects the main elements of household energy use patterns in Greece by smearing a quantitative approach. Their results suggest that the typical energy-saving consumer is a comparatively well informed and environmentally aware individual with a rather high incomes living in her own house.

Straightforward questions regarding electricity bills, knowledge about energy efficiency, and knowledge about appliances, asked to 600 respondents in Beijing (China) and the researchers [7] reported low level of general knowledge and awareness about electricity. Similar studies in China [7] and United States [8] reported the consumers pay the electricity bills by due date but they ignore the particular details of kWh consumed (electricity bill size). Surprisingly, only 2 percent respondents receive the information and brochures displaying the actual ways to improve the efficiency and reduce the electricity use [7].

Cost is the prevailing factor affecting energy efficiency promotion in Liaoning Province of China rather than environmental protection [7].Yasuhiro Fuwa [9] sheds light on very little awareness of the energy efficiency of appliances, the price of the services that appliances produce, or electricity rates in Japan.

Financial and aesthetic aspects reported as major hurdles on the way of household energy efficiency [12]. Poor communication with households, limited scope & scale [14], lack of objective behavioural data and institutional barriers to integrating disciplines' [14], [16] are also noted as significant impediments to develop more integrated approach to analyse household energy efficiency. Wood and Newborough [26] reported energy savings of more than 10% (20% in some of the groups) in households included in their study by applying different information strategies. Similarly, Darby [27] reported reduced consumption by up to 20% in cases where improved feedback was used.

III. Energy Consumption Pattern

Kowsari R, Zerriffi H [10] comments that the energy ladder concept can only provide a very limited view of reality.

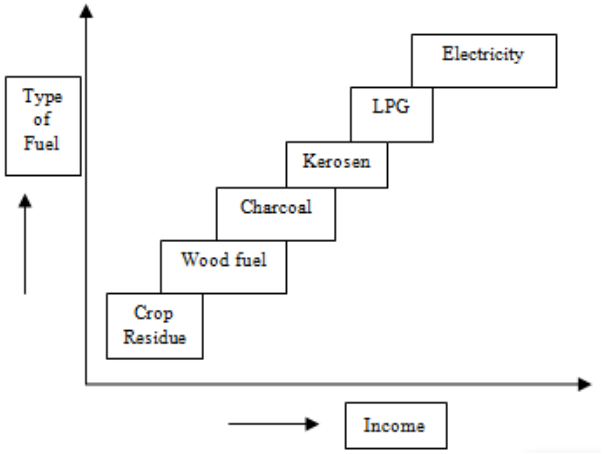

Figure 2. Energy ladder.

The energy ladder shown in Fig. 2 describes a pattern of fuel substitution as the household economic situation changes [11]. We changed the concept of energy ladder varying the length of rectangle which represents the percentage of usage of fuel in current scenario.

Household energy choice is governed by closely interrelated a) Endogenous factors and b) Exogenous factors refer Table I [10].

EleniSardianou [25] verified the negative association of larger electricity expenditures and attitude towards acceptance of energy conservation strategies, whereas the sex, marital status and educational level of the respondents are not the predictors of energy conservation behavior. This is quite incongruous with the data given in Table I by researchers although EleniSardianou use mathematical equation numbered as (2).

$$CONSERVEi=\alpha_0+\alpha_1AGEi+\alpha_2SEXi+\alpha_3UNIVi+\alpha_4MARRIEDi+\alpha_5MEMBERi+\alpha_6LNINMONi+\alpha_7LNELi+\alpha_8OWNHi+\alpha_9TYPEHi+\alpha_{10}NOROOMSi+\alpha_{11}TM2i+\alpha_{12}INFOENVi+\alpha_{13}CRESPi+u_0 \quad (2)$$

TABLE I. SUMMARY OF FACTORS DETERMINING HOUSEHOLD ENERGY CHOICE

Categories	Factors
Endogenous factors (household characteristics)	
Economic characteristics	Income, expenditure, landholding
Non-economic characteristics	Household size, gender, age, household composition, education, information
Behavioural and cultural characteristics	Preferences (e.g. food taste), practices, lifestyle, social status, ethnicity
Exogenous factors (external conditions)	
Physical environment	Geographic location, climatic condition
Policies	Energy policy, subsidies, market and trade policies
Energy supply factors	Affordability, availability, accessibility, reliability of energy supplies
Energy device characteristics	Conversion efficiency, cost and payment method, complexity of operation

where AGE is the age of the correspondent; SEX is the sex of the correspondent; UNIV is a dummy variable indicating whether the respondent has completed undergraduate studies or not; MARRIED is a dummy variable indicating whether the respondent is married or not; MEMBER is the number of household members living in the same residence; LNINMON is the natural logarithm of monthly private income of the respondent measured in Euro; LNEL is the natural logarithm of household's expenditures for electricity in euro as they recorded in the last electricity bill; OWNH is a dummy variable indicating whether the household owns his dwelling; TYPEH is a dummy variable indicating whether the household resides in a detached house or not; NOROOMS is the number of rooms of household's dwelling; TM2 is dwelling size in m^2;INFOENV is a dummy variable indicating whether the respondent is informed about the global environmental problems; CRESP is a dummy variable indicating whether the respondent recognizes his contribution to environmental problems and u is an error term.

IV. REVIEW OF ENERGY EDUCATION EXPERIMENTS

Jenny Palm [12] conducted a case study in which the energy consultant was appointed to provide guidance about energy efficiency to the Swedish households. The respondents demanded more tailored information on how to reduce the consumption only through free and independent sources.

A project named "Energy hunt" run in 2005-2006 by energy consultants in Linkoping with the goal of fostering the sustainable energy use [12]. The project reduced the household energy consumption by 10 percent only due to behavioural change. Studies reported the strong resistance from the respondents towards government involvement into their private sphere.

Konstantinos P. Tsagarakis proved education could transform human behavior towards the rational use of energy and increase energy literacy [22]. Energy researchers claim multiplier effect of energy education under the assumption that "converted" pupils shall influence their peers and other people in their environments (family, relatives, friends, neighbors). However, Cathy Mullaly [24] debates the effect of home energy reductions is maintained only over intervention period i.e. once the technique is removed home energy reverts to previous levels.

According to Rubens, Cristiano [29] energy education is effective means to overcome the barriers of energy efficiency such as a) institutional b) market c) organizational and d) behavioral.

V. USE OF ENERGY EFFICIENT HOME APPLIANCES

Feng, Benjamin [7] conveyed following findings. Firstly, the populace do not know the difference between energy efficient and inefficient lamps. It is interesting to know, the respondents attributed themselves owning more fluorescent and compact fluorescent light bulbs when they did in fact not.

According to Yoshihiro Yamamoto, Akihiko Suzuki [9], decision-making in electrical appliance use and electricity consumption in the home is not always normal and exaggerated by both the characteristics of particular appliances and the payment system for electricity consumption along with human psychology.

Studies [9] reported interesting result that the refrigerator is among least cared-about appliances being second heaviest electricity consumer in the home after an air conditioner and lighting is among the more cared about despite its being regarded as the least electricity consuming.

VI. ENERGY INFORMATION SYSTEMS (EIS)

Providing household members with information on actual domestic energy-consumption is most competent way to achieve energy efficiency. A number of investigates have been conducted in this regards; e.g. Newborough [16] analyzed the effectiveness of an appliance-specific display showing the energy consumption for cooking, and classified the features necessary for displaying energy information [17]. Brandon [18] analyzed the most effective energy-saving technique among several feedback methods using, for example, computers, leaflets, etc. Egan [19] investigated the relationship between different display formats and the reaction to each from informants. Additionally, Osaka Gas developed an energy-consumption information service in an experimental apartment house called ''NEXT21''. This service included measurements of not only electric power, and heated-water supply, but also displays graphs of consumption charges on a web browser [20]. However, Osamu Saeki, Kiichiro Tsuji [21] report that in these researches, the energy awareness behaviors of the consumers induced by the energy information systems were not discussed in detail.

Tsuyoshi Ueno, Fuminori Sano [21] installed ECOIS (Energy Consumption Information System) in few household of Kyoto (Japan) and analyzed the effects with following amazing findings. Firstly installation of the

system led to 9 percent reduction in household power consumption. Secondly the comparison of daily load-curves and load-duration curves for each appliance, before and after installation, revealed various energy-saving behaviours' of the household members. The ECOIS is shown in Fig. 3.

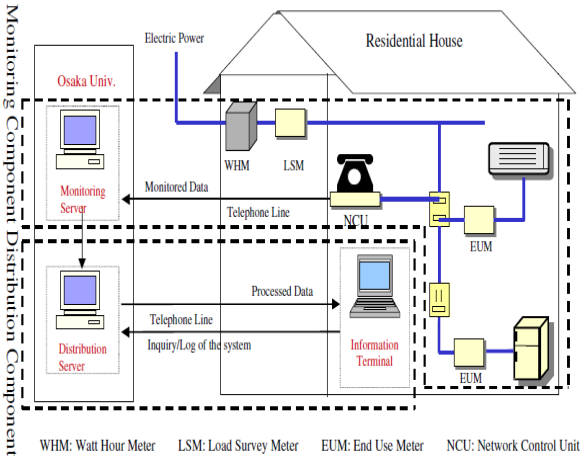

Figure 3. Configuration of ECOIS.

VII. Suggestions and Recommendations from Energy Researchers

Jianhua Yin, Yixiang Zhang [1] suggests interest organisations, authorities' and residence communities to promote energy education programs. Education campaigns' have stronger emphasis on disseminating electricity saving measures. Patrik Soderholm [4] stressed that, apart from informative policy measures, the other policy efforts such as taxes, subsidies and infrastructural norms play equally important roles in influencing households' energy saving behavioural patterns.

Feng, Benjamin [7] suggest augmentation and modification in Government policies focussing on additional subsidies and rebates, which could help households to purchase energy efficient lights and appliances. They also reported that education programs overcome resistance and lack of consumer awareness relating to electricity consumption and energy efficient labels.

To create sustainable society populace should understand own responsibilities willingly [12], [13]. It is interesting to know the households spontaneously say that the other people need to become aware and they point towards government and authorities for not undertaking greater number of intensive initiatives to change the energy behaviour. If information combined with feedback and measurement technique, the energy use may be successfully reduced [12].Schools should have a well-defined policy on energy education with a member of staff responsible for its implementation, coordination and up-dating [23].

Iana Vassileva, Fredrik Wallin [28] recommends energy companies and municipal authorities to include individual assessment approach to households' energy consumption when developing energy saving strategies and measures.

Paritosh Nandi, Sujay Basu [30] implied Government of India to collect small energy cess on every type of energy sold which further used to create energy awareness and train the people. It is necessary that the energy consumer must be aware of the technology and he should have access to finance with risk cover in order to overcome the energy efficiency gap in the household sector of India. Researchers suggest provision of better incentives for particular home type, developing institutional mechanism in the above context [31].

VIII. Research Openings in Dwelling Energy Efficiency

Energy scholars presented the consumption for one of the regions in China [7]. However, there is need to establish the relation between the electricity consumption and type of home, usable area of home etc.

Cathy Mullaly [24] suggest further research to maintain the long-term effectiveness of energy efficiency strategy.

If consumers must be encouraged to perform energy audit of his home, [31] more elaborative approach need to develop to train the consumer technically. Again, the energy audit requires costly instruments e.g. Anemometer to measure the velocity of air in the air conditioner, Energy Meter to measure the power consumption.

As said by Wood G, Newborough M [26] detailed study should be undertaken to better understand how consumers interact with, and are influenced by, ECI (Energy Consumption Indicators) to optimise energy saving potential.

IX. Conclusion

Literature identifies wide range of determinants to predict household electricity use behavior but there is need to highlight only few based of continental, countrywide, local behaviors. Authors argue to differentiate the perceptions regarding above issue among developing countries like India, Sri Lanka, Myanmar and developed countries like UK, Sweden, and France etc. We suggest e for more detailed research in the context of operation and manoeuvre of energy efficient appliances. The authors also recommend designing FBEBS (Feedback based electricity billing system) which help to conserve the energy in way that is more efficient. Khuong Minh Vu [7] foreseen that, the energy efficiency will not occur itself, nor will most consumers educate themselves about electricity and electricity use. Therefore, in above reference, we propose strategic command and control support system for household energy management, which encompasses the energy efficiency to occur itself. However, we stress on continuous monitoring, evaluation and updating of Government policies and incentives. In relation to ECOIS [21], the authors suggest including financial unit in the model, which further reduces the energy consumption, and enhance general energy awareness. We recommend not only schools but

engineering institutes also to take opportunity to make people energy literate in collaboration with energy distribution companies.

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