Assessment of the Impact of the occupants' Behavior on Energy Consumption in a Residential Building, Pune

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Abstract

There are many factors which influence the Energy Consumption of the building such as, type of Electrical and Plumbing system, lighting system, and other technical systems, etc. Of the many factors, Occupancy level and its behavioral pattern are often neglected in the initial design stage of the building and this adversely impacts the building performance after it has been fully occupied. The Residential sector is the largest and the fastest growing sector in current scenario. It has a significant contribution towards Energy consumption in the construction industry.

This paper discusses and unfolds the relationship between Occupant Behavior and its impacts on Energy consumption. It focuses on the lifestyle and their attitude towards pro-environmental behavior. In conclusion, the paper shows that the main controversy between investing in energy efficient installations and exhibiting energy saving habits are influenced by key factors like, age, gender, and income levels. It is important to that we have a balance between our attitudes towards energy savings and related investment issues. Through awareness campaigns, the users must be motivated to engage in energy conservation behavior.

Keywords

Occupant Behavior, attitude, habits, Energy Consumption, Environmental awareness,

Pro-environmental Behavior

1. Introduction

Being a developing country, power consumption has been increasing at greater pace in India. Building industry is one of the largest consumers of energy and thus has a high potential of saving the consumption as well. Currently, the residential and commercial sectors account for 30% (22% residential and 8% commercial) of total electricity use and consumption in these sectors is rising at 8% annually (Kumar, 2011). As energy consumption from residential buildings is predicted to raise by more than eight times by 2050 under the business as usual scenario, it is of vital importance for India to develop energy-efficiency strategies focused on the residential sector to limit the current trend of unsustainable escalating energy demand (Residential buildings in India, projections and saving potential, 2014).Residential Sector forms a major proportion of the Building Industry.

Indian power generation is mostly dependent on fossil fuels, and renewable energy resources. Coal is the key source of CO2 and primarily responsible for global warming. Indian residential sector is majorly contributing towards the growth in the carbon footprint.

Therefore, today, we are moving towards Green Building Concept as a sustainable approach. But, that is not enough. People lifestyle and attitude towards the Environment greatly impacts the Energy Consumption of the Building. Basically, Once the person has occupied a building, whether it is a conventional one or a green-rated one, it is important to have a good approach/ awareness about the environmental impacts by the Occupant, so that, it would save on energy consumption of the building and reduce the pressure on the use of non-renewable sources, which is very much necessary in current scenario of increasing urbanization. Not having a pro-environmental approach affects the energy usage and adversely impacts the environment.

1.2 Pro-environmental behavior and energy savings in households

There is a vast difference between the Energy uses of a similar typology of flat and family pattern in the same housing society. This is because of the variations in the lifestyle, culture, economy, and psychological factors. Raising awareness and sensitivity towards enhancing the quality of the environment through a sustainable approach minimizes the pressure on use of fossil fuels for energy generation and ultimately saves on the energy costs. A child should be raised in an energy conscious environment. Indeed the technological solutions for the building envelope and efficiency of the building systems were optimized and now the success of this high-performance of the buildings depends on how occupants interact with them. (Veena Barthelmes, 10-11 May, 2017).

Pro-environmental behavior is an environment- friendly approach towards minimizing the harmful impacts on the environment. It is classified into two types- 1. Impact-oriented behavior- It is defined by the change that it has on the natural resources and ecosystems. 2. Intent-oriented behavior on other hand is behavior that is carried out to positively impact the environment. (Felixdottir, June. 2017)

Both orientations are important. A simple example of pro-environmental behavior in daily life is, purposely turning off the lights when leaving a room, recycling, use of public transport, etc. Pro-environmental behavior might not be convenient or comfortable sometimes. People often perceive that their individual behavior does not really matter in the wider context, and therefore are not willing to make sacrifices to take up a more environment friendly lifestyle. People may believe that there is a vast difference between environment friendly and living a happy and meaningful life. On the Contrary, research has shown that individuals who live an environment-friendly life tend to be happy and contented. (Kasser, 2005). It is important for an user to foster energy saving habits.

1.1 Different behavioral perspectives towards Energy Use.

The total energy use of the building can be clearly calculated after understanding the occupants' influence over the end uses of energy. Each and every occupant has a different approach towards using any installation or electrical system in the building. The main factors affecting the occupants' behavior are social, psychological, physical, and biological. Energy-related occupant behavior is related to building control actions (in order to control the indoor environmental quality) as well as household or other activities. (Yoshino, Nov. 14, 2013). Human actions affect the building energy use as they control the working of various electrical appliances in the building such as, setting the temperature for heating and cooling, turning the lights on/off, opening of windows, use of laptops etc. The occupant behaves in a certain way because of external aspects such as physical conditions of the building, its location, thermal comfort, visual comfort, etc. Various field studies measured the impact of occupant-driven parameters on energy consumption in residential buildings. The outcomes showed large discrepancies in the effect of occupant behavior among houses in a single community, with corresponding large impacts on energy consumption of over 300%. (Veena Barthelmes, 10-11 May, 2017) That is why, the study of occupants 'lifestyle, routine, his culture, psychological aspects is significant in knowing the exact energy use and modifications in their behavior would definitely change the usage pattern and help in Energy savings.

Barriers in adopting pro-environmental behavior and its consistency in maintenance

The users face many barriers in adopting an eco-friendly attitude which helps in conserving energy. The key barriers include awareness, income levels, age, and typology of region i.e rural area or urban area. For example, People with lower income levels cannot purchase energy efficient devices for their households. Lack of knowledge about the energy efficient measures, reluctant to sacrifice their comfort zone and spend on energy saving measures, common psychological tendency "No big difference is going to happen, if I am the only person to save energy", are some of the mainstream but important barriers which we need to overcome to help in energy conservation and adopt a consistent pro-environmental approach.

2. Aims and Objectives of the study

The main aim of the research is to analyze the relationship between occupants' behavior and its impact on energy consumption in a residential building.

The objectives of the study are:

1. To analyze the significance of having a pro-environmental approach to reduce the Energy consumption of the building and thus, have minimum impact on the environment.
2. To analyze the barriers towards adopting pro-environmental attitude.

3. Hypothesis statement

Pro-Environmental Behavior of the Occupant decreases the energy consumption of the Residence.

4. Literature review

In a research paper by Veena Barthemles, simulations were carried out of a residential building by regulating the occupant variables and study its impact on the building energy performance. The simulation was compared between two buildings- 1. A nearly-zero energy residence and 2. Traditional design residence. The occupants affected the energy consumption at different levels. In this study, three different styles of occupant behavior lifestyles i.e. 1. Standard consumer 2. High consumer

3. Low consumer were analyzed by considering different types of interactions between the occupants and the building envelope systems, ventilation, lighting, heating and cooling systems, etc. The simulation was done referring to the Italian standards. The simulation results show the annual primary energy consumption divided by end-uses (space heating, cooling, lighting equipment, pumps, and fans.). The result of the study concluded that loads generated by the occupants have greater influence over Traditional design residence.

A survey was carried out to study the relation between Environmental knowledge, pro-environmental behavior, and energy savings in households. The consumers were told about the benefits of pro-environmental behavior

and how it will help the cutting on the energy costs. In this study, frequency of household appliance use was also evaluated. The study revealed that impact of environmental knowledge changed the consumers 'perspective towards the use of energy and thus, lowered their energy use expenditures.

Using the simulation program ENERWIN in order to evaluate the reasons for its high electrical use in 30 residences in Kuwait, allowed for researchers to reach the conclusion that annual energy use in residential buildings was directly related to occupant's location and life-style, and that data relating with the type of occupant should be as accurate as possible. The Markov model was used to analyze air conditioning on/off state systems and to determine effective schedules for air conditioning operation from inhabitant occupancy schedules. What influences occupant behavior in turning on and off the air conditioner is reflected by social background, such as energy cost and moral sense. (Vivian Tam, 23 rd july, 2018)

5. Methodology

Sample

The study population constitutes multi-person households male-female adult couples, elderly users and children below the age 20. A total sample of 80 such occupants was studied from 2 residential apartments in the city of Pune, India. Both the residential apartments (A and B) house higher-middle economy class people. From the list of flats, random samples of 17 (6 units of 3BHK and 11 units of 2BHK) flats consisting of 2BHK and 3BHK units were analyzed. At least 2 attempts were made to contact each household face-to-face were made at different times of the day. Remaining Occupants refused to participate. Response rate was as low as 20%.

Table 1 compares the daily energy consumption of two 2BHK units consisting of a family of four occupants each, from residence A and B. The average area of each unit is 90 sq.m. The Family consists of an adult couple and two children below the age of 20.

Table 2 compares the daily energy consumption of two 3BHK units consisting of 6 occupants each, from residence A and B. The average area of each unit is 100 sq.m. The family in each unit comprises of an adult couple, two children, and an elderly couple.

Table 3 compares the annual energy consumption (EPI) of both Residential apartments A and B.

Whereas, the daily energy consumption data is divided into four categories: 1. Interior Lighting

2. HVAC 3. Hot water system 4. Appliances as shown in the respective tables.

6. Observations and Analysis

Sample of 8 occupants were analyzed.

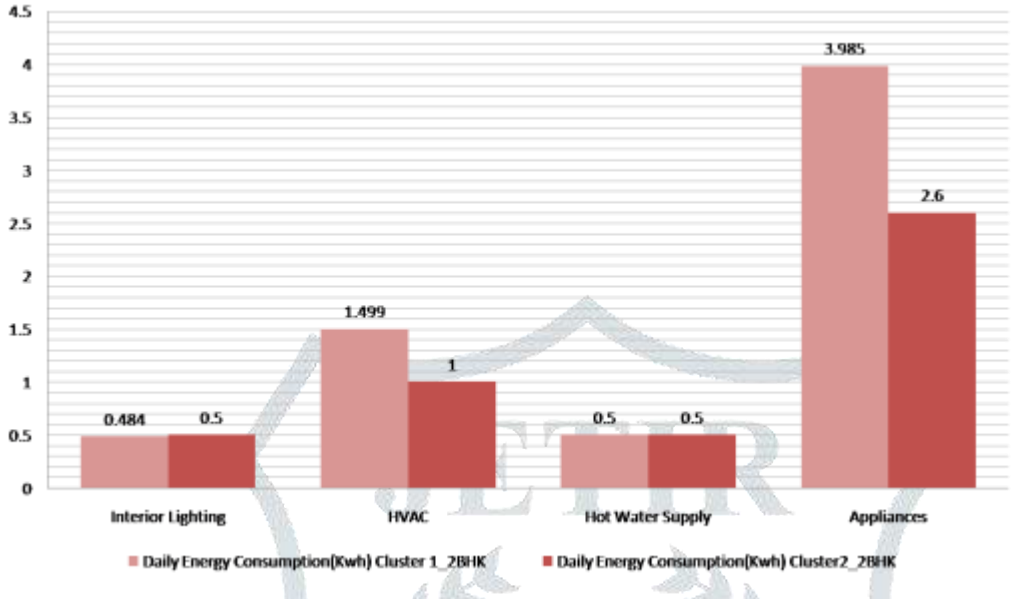

Figure 1 Graph showing the daily energy consumption of two 2BHK flats .

Effects of Occupant Behavior

The above 2 clusters (2BHK flats) have an average area of 90 sq.m.each. As shown in the fig.1, HVAC and appliances (Refrigerator, Television, Laptop, Iron, Water purifier and Mixer) form the two largest categories of end-use loads in terms of daily energy consumption in the 2 clusters, while Interior lighting and Hot water supply have modest contribution. Also, the two largest loads exceed the other two end-use loads that do not have significant variations in the proportion amongst them. This indicates that occupants in different clusters had similar behavior. Moreover, there is a noticeable increase in appliance usage proportion in cluster 1 as compared to that in cluster 2, which is mainly characterized by the higher frequency and duration of the appliance use by the occupants in cluster_1 2bhk flat. As observed from the field study, the duration of occupancy in cluster 1 is higher than in the cluster 2. Both the clusters have same typology of family i.e. 4 users each flat, with 2 occupants (couple) aged between 30-35 years and 2 children (daughter and son) aged between 10-20 years. The difference was observed in their occupation pattern. One of the elderly users in cluster 1, who is a female, occupies the house for 24 hours. Therefore, it affects the appliance and HVAC usage in the house. This user prioritizes thermal comfort over expenses.

6. Observations and Analysis

Sample of 12 occupants were analyzed.

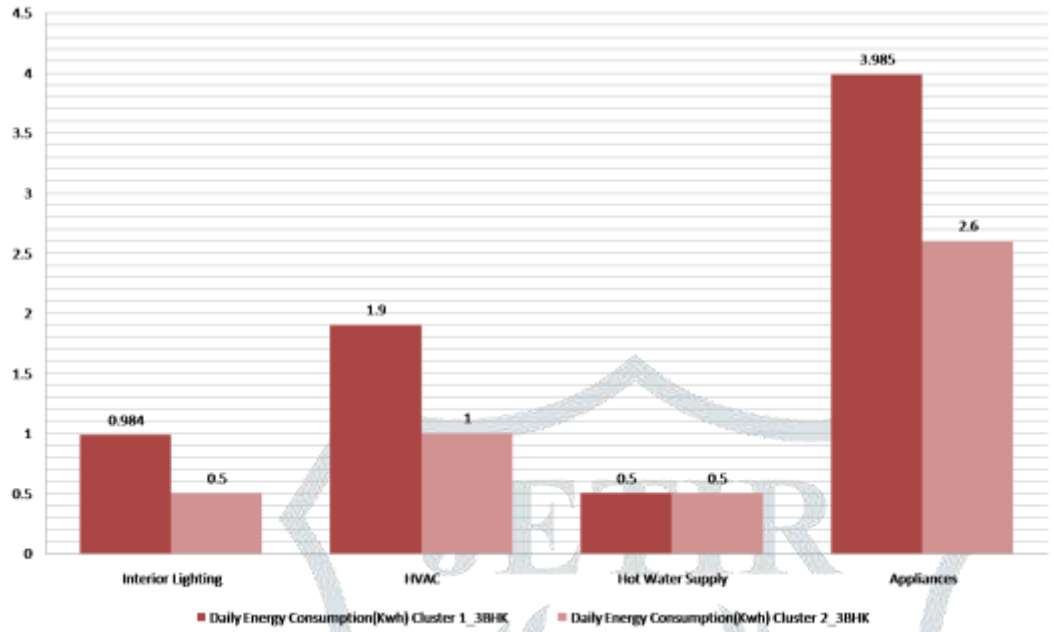

Figure 2 Graph showing the daily energy consumption of two 3BHK flats .

Effects of Occupant Behavior

The above 2 clusters (3BHK flats) have an average area of 100 sq.m.each. As shown in the fig.2, Cluster 1_3BHK unit have higher energy consumption in Interior lighting, HVAC and appliances than the daily energy consumption of Cluster2_3BHK. Whereas, both units have same consumption for hot water supply system. This indicates that the occupants have similar behavior towards the use of hot water supply. The drastic increase in the consumption due to appliances is characterized by the usage pattern by the elderly couple in the Cluster1.The senior male user in the house is physically disabled, due to which the senior couple stays in the house for almost 24 hours of the day. This increases their appliance and lighting use like using Television for entertainment purpose for the entire day, keeping the lights on during night time in areas like bathrooms, toilets, and common passage. The adult couple belongs to working class. Both children use laptops.

Whereas, Cluster 2_3BHK elderly occupants do not stay at home for longer periods. Thus, their energy consumption is comparatively less than Cluster1-3BHK.

6. Observations and Analysis

Annual Energy Consumption (EPI) of Apartment A and B.

Area of Apartment A : 18,000 sq.m.

Area of Apartment B : 14,000 sq.m.

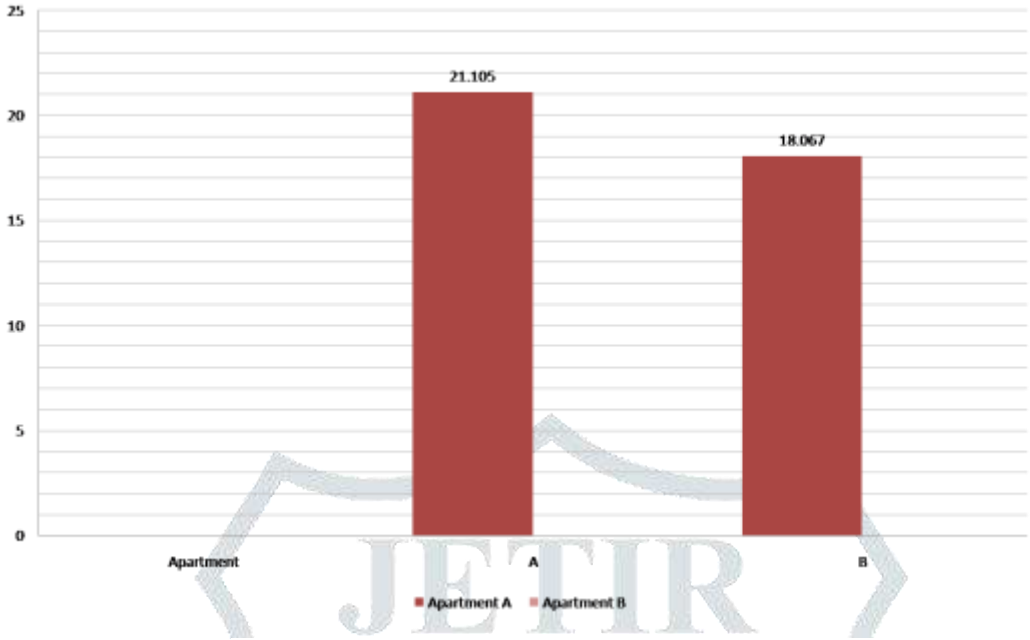

Figure 3 Graph showing the EPI value of 2 Residences.

Comfort vs. Economy-

As shown in the fig. 3, The Annual Energy consumption of Apartment A is higher than Apartment B. From the field study and observations, it is observed that both residences have similar area and similar family typology as mentioned before. The difference was observed in economic class and the occupancy pattern. Residence A has installed Air-conditioners in each of their household units. They are ready to pay to install energy efficient devices in their households and are lenient towards Energy efficient behavior. Whereas, Occupants in Residence B show conscious efforts towards money savings and possess energy efficient approach towards environmental issues, like, turning off the lights while leaving a room, minimal use of electrical devices. As observed, the economy class of Residence A occupants is higher and more luxurious than the occupants in Residence B.

Other factors influencing energy consumption values

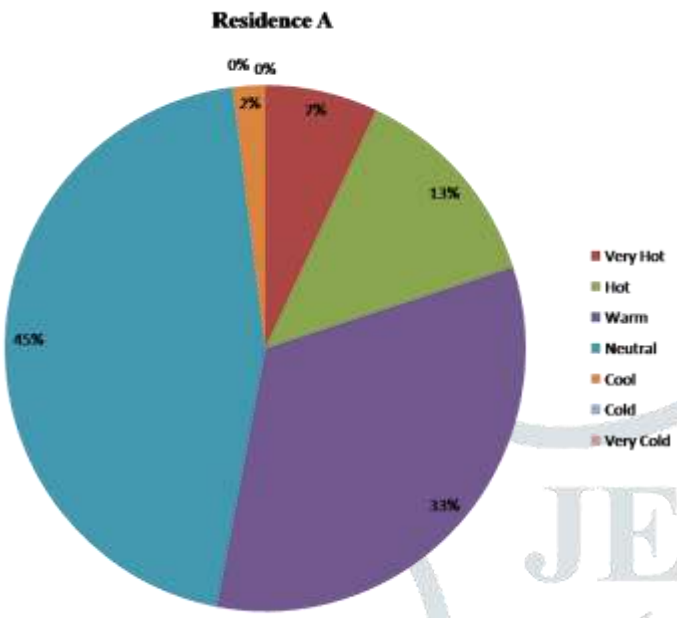

Figure 4 Thermal comfort classification for March in Residence A.

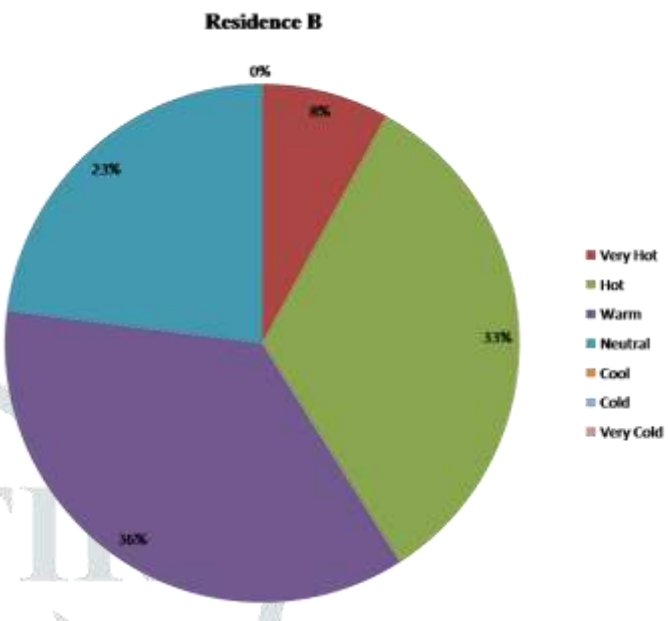

Figure 5 Thermal comfort classification for March in Residence B

Samples of 80 occupants were analyzed under Bedford's extended scale to measure thermal comfort status of the users. The readings were taken for two different times of the day for two days in the month of March. As shown in the fig. 4, 7% occupants are not comfortable in their households and they have to rely on artificial ventilation applications. As observed, Residence A is designed to have a good ventilation throughout the structure and occupants are thermally comfortable. Since Residence A has more occupancy level than Residence B, it has higher EPI value.

As shown in the fig. 5, the residents in B are not thermally comfortable and their use towards electrical appliances for cooling is higher as compared to Residence B.

Also, from the observations, the income levels of occupants in residence A is higher than the occupants in Residence B. Residence A occupants show more concern towards energy saving than Residence B occupants. Residence B occupants are more stringent towards spending for any energy efficient installation in their building.

Conclusions

Residential sectors can achieve cost-effective reduction of energy consumption in buildings. This can be done by proper design and construction of the buildings at the initial stage. Cost-effective retrofitting measures can also be adopted. Moreover, after the occupancy of the building, inducing energy-saving and eco-friendly habits

amongst occupants can save on the energy consumption. From the observations and analysis, it is clear that, most of the households with higher income levels are ready to invest in Energy-saving installations but do not show energy conservation habits in their day-to-day life. They are not ready to sacrifice their comfort over energy savings. Also, household with higher education and income levels show awareness towards environment protection and energy savings, but this percentage is as less as 10%. Whereas, some of the households with lower income levels are consistent in energy savings and show pro-environmental approach, as well as, they are ready to pay for energy saving installations, but up to a certain limit. Since, these installations are expensive at their initial stage and are often not affordable for the middle-class occupants.

The above study and analysis show that pro-environmental approach saves on consumption of energy. But, there is no consistency towards their eco-friendly approach. And sometimes, the occupants show casual behavior towards energy saving and more focus towards monetary savings. The occupants must be motivated to indulge in environment protection drives. The government policies should take up initiatives to keep a check on the execution and maintenance of the energy conserving installations.

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