ENERGY EFFICIENT BEHAVIOURAL TRENDS IN RESIDENTIAL SECTORS FOR LOW-INCOME CULTURAL BACKGROUND: A CASE-STUDY OF SLUMS IN CHITTAGONG, BANGLADESH

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Slums may be a by-product of the urbanization process in a developing country like Bangladesh. The slum dwellers' lack of energy awareness is the primary impediment to domestic energy savings. In countries such as Bangladesh, where wages are extremely low, energy awareness is primarily focused on behavioural issues. This study presents the results of an energy awareness feedback program on the energy-efficient behaviours of various groups of slum occupants in Chittagong, Bangladesh. All slum occupants are classified here according to their housing structure and economic circumstances. Initially, occupants are informed about the various solutions and opportunities for energy conservation through low- or no-cost measures. Following that, a survey was conducted (between May and June 2020) in 54 individual houses (similar in size but with varying housing structures and economic conditions) in slum areas to ascertain the impact of efficient energy behaviour on lighting and appliances. A statistical analysis (two-way ANOVA) was conducted to determine the efficient energy behaviour trends associated with the selected housing groups' structure and economic conditions. The study will aid in the implementation of several actions aimed at addressing various energy-efficiency issues affecting low-income communities in Bangladesh.

Keywords: energy efficiency; residential; slums; statistical analysis

INTRODUCTION

Since the onset of the economic crisis in the majority of industrialized and developing countries, the rate of energy efficiency improvement has slowed (Yang and Zhao 2015, Karim *et al.,* 2017). Buildings are often the largest end-user sector, followed by transportation (32%), industry (26%), and agriculture (2%) (Bosseboeuf 2015; Yang and Zhao 2015). In certain countries, such as Hungary, Latvia, and Estonia, the building industry consumes more than 45 percent of overall energy consumption (Bosseboeuf 2015). Regrettably, this industry has received little attention in developed and developing countries alike, despite the fact that it urgently requires

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energy conservation measures. In developing countries such as Bangladesh, India, and Pakistan, newly constructed or refurbished buildings consume an enormous amount of energy; therefore, effective energy refurbishment is critically needed in these regions (Bardhan *et al.,* 2018; Debnath *et al.,* 2019). At the moment, it is widely acknowledged that the building/construction industries are incapable of sustaining energy efficiency projects in the absence of appropriate government rules and regulations (Elsharkawy and Rutherford 2015). Nonetheless, many government institutions at the national or local level lack information and expertise about possible policies, techniques, and tools within their particular context (Bardhan *et al.,* 2018, Debnath *et al.,* 2019; Uddin *et al.,* 2021). Without well-designed policies, techniques, or instruments that typically affect both the energy demand and supply sides of the equation, improvements in building energy proficiency will continue to progress at a slower rate (Elsharkawy and Rutherford 2015; Yang and Zhao 2015). Typically, in the majority of fast-growing developing countries, the housing/residential sector represents the most cost-effective and feasible opportunities for energy efficiency programs, as well as the largest co-benefits. However, several hurdles must be controlled/removed in order to turn these opportunities into reality (Elsharkawy and Rutherford 2015). The United Nations Development Programme (UNDP) and the International Energy Agency (IEA) are proposing several cross-cutting programs to disseminate their most recent study, findings, and recommendations to encourage policymakers to implement various energy efficiency programs in the housing sector methodically, thereby reinforcing excellent cooperation for energy efficiency schemes in both developed and developing countries (Uddin *et al.,* 2019; Debnath *et al.,* 2020). Despite rapid advancements in the housing sector's impact on energy consumption, resource depletion, and waste generation, the built environment (e.g., housing, infrastructure, and cities) continues to be critical to a country's economic development, particularly in newly industrialized and developing countries such as Bangladesh. This has a significant impact not just on the residential sector in Bangladesh, but also on the entire construction industry, which is a major candidate for sustainable growth (Yang and Zhao 2015; Uddin 2018; Uddin *et al.,* 2019; Uddin *et al.,* 2021; Uddin *et al.,* 2021). However, as a developing and overpopulated country, sufficient modern energy is critical for the country's economic and health sectors (Kabir *et al.,* 2017; Uddin 2018).

Bangladesh is a low-energy-consumption country with an area of approximately 147570 square kilometres and a population of approximately 164 million people. Although only 30% of the population lives in urban areas, the country's per capita primary energy consumption is extremely low (Kabir *et al.,* 2017; Karim *et al.,* 2017). In general, approximately 60% of Bangladesh's population lacks access to adequate electricity, while only 1.5 million households rely on natural gas to meet their energy needs. Additionally, nearly 90% of households in Bangladesh cook with biomass, while the remainder use LPG, natural gas, or biogas (Kabir *et al.,* 2017; Uddin 2018). Domestic energy consumption is inextricably linked to the country's standard of living and economy in this country. Typically, a large number of poor people migrate from rural areas, and the very poor in urban areas live in slums. Improving the energy efficiency of this largest segment of the poor or low-income population (e.g., slum dwellers) is critical for a long-term solution to Bangladesh's energy scarcity (Rashid 2009; Uddin 2018). They are typically integrated into larger energy policy initiatives. However, governments may choose to implement specific measures to increase energy efficiency adoption among slum dwellers (Uddin 2018). Generally, energy efficiency has never been a national priority in extremely low-income housing (e.g.,

slums). National funding or initiatives to improve the living conditions of slum dwellers and energy efficiency have been woefully inadequate. Additionally, there is a significant disparity between energy consumption and efficiency among slum dwellers in Bangladesh, and unmet energy requirements impede the country's development toward Vision 2021. (Kabir *et al.,* 2017). Although very few people living in slum areas have access to electricity, the scenario of energy conservation awareness is at an acute level for this particular low-income population, as slum dwellers are unaware of the sustainable development goal. Thus, energy literacy, awareness, and conservation behaviour among slum dwellers are critical, as energy consumption in this sector represents a significant opportunity for resource conservation. In this regard, energy audits, peer feedback, and awareness are all extremely effective methods for determining individual needs, particularly for slum dwellers (Steg 2008; Zvingilaite and Jacobsen 2015). Additionally, it is a pioneering and evolving effort to bring attention to and increase the urgency of addressing a persistent problem that is all too frequently overlooked in discussions of environmental, energy, and economic issues. Recognizing the significance, a study on the energy consumption habits of slum dwellers in Chittagong, Bangladesh, was conducted. A preliminary energy awareness feedback program was conducted with selected slum dwellers (N = 54), followed by a questionnaire and survey data analysis using two-way ANOVA (e.g., energy bill, income level, etc.).

In this case, a combined approach is preferable to others. The study's distinguishing feature is that households are classified according to their income level and housing structure. The primary goal of this study is to accurately reflect the effects of energy consumption patterns on various slum dwellers following the implementation of a peer feedback program through the use of factual statistical analysis.

This article is structured as follows, section 2 describes the literature review of the study; section 3 explains the research method; section 4 describes the results and discussions, and section 5 concludes the study.

LITERATURE REVIEW

Low-income residents

Numerous studies have revealed that nearly 90% of households in the capital city of Dhaka's municipal poor areas have access to electricity. However, the electricity infrastructure in slum areas is woefully inadequate in terms of affordability, accessibility, and reliability (Rashid 2009; Kabir *et al.,* 2017; Karim *et al.,* 2017). While low-income households in slum areas are covered by insufficient energy access, it is frequently used illegally at a very high cost. Additionally, the studies revealed that residents of slums are unaware of energy conservation or savings programs, and there is no energy review or active inspection by any agency or group (Rashid 2009; Karim *et al.,* 2017). Additionally, several empirical studies (Bhide and Monroy 2011; Kowsari and Zerriffi 2011; Bisu *et al.,* 2016) have demonstrated the impact of energy education on stacking methods, which contribute to an understanding of low-income residents' sociocultural energy demand practices. All these findings have emphasized the importance of energy conservation as a socio-technical method for promoting energy savings in areas such as cooling, heating, lighting, and cooking. Debnath and Bardhan's research revealed that low-quality slum treatment may have a detrimental effect on energy sustainability, dwellers' health, and inhabitants' well-being (Bardhan *et al.,* 2018; Debnath *et al.,* 2019). A similar study on the rehabilitation of slum housing in India indicates that a substandard built environment forces resident into

energy poverty by increasing their home energy bills (Debnath *et al.,* 2019). Tulsyan *et al.,* (2013) examined the effect of the Energy Conservation Building Code (ECBC) on the energy-saving options available to a large number of low-income households, demonstrating that the building envelope can save up to 15% of total energy consumption. Devi and Palaniappan (2014) proposed an existing energy assessment influence sequence for a case study dwelling in South India, in which they counted the dwelling's embodied, operational, demolition, and entire lifecycle energy consumption. According to Gillingham and Newell (Gillingham *et al.,* 2006), low-income residents are more likely than high-income residents to be harmed by economic difficulties when choosing energy-efficient deals, implying that subsidization approaches benefit low-income residents.

Intervention policies

It is demonstrated that resident behaviour plays a significant role in energy consumption, consistent with previous research on various intervention strategies for changing behavioural practices. As an effective behaviour measure, a few studies (Pisello and Asdrubali 2014; Azar and Al Ansari 2017) have presented a target direction for residential dwellers' intervention planning, which is associated with the design process of persuasive systems (Oinas-Kukkonen and Harjumaa 2009), which may contribute to the advancement of effective actions to change occupants' behaviour and improve sustainability. Additionally, other studies (Wyon *et al.,* 2006; Höök and Tang, 2013) observed specific social interventions that reduced energy consumption by up to 20% while implementing several energy behaviour transitions and action plans. In this context, deliberate social interventions are used to alter occupants' energy consumption behaviours. The method used in social interventions is largely determined by the users in question and the issues/problems that need to be addressed (Elsharkawy and Rutherford 2015). Energy-related social interventions are particularly beneficial when they are tailored to the occupants' interests and are cost-effective in terms of time, effort, money, or social dissatisfaction, and when occupants do not face severe behavioural limitations (Steg 2008). Additionally, interventions can reveal environmentally unfriendly behaviours/attitudes and explain why homeowners/inhabitants are resistant to implementing sustainable behaviour profiles. These findings all assist researchers in determining the most effective intervention method to use. Zvingilaite and Jacobsen (2015), for example, emphasized the benefits of consistent intervention, prolonged, disaggregated, and continuous feedback. Another study (Faruqui *et al.,* 2010) discovered that providing direct feedback via an In-Home Display (IHD) encourages residents to adopt more energy-efficient behaviours. However, a growing body of research has begun to examine several contextual factors (e.g., social, economic, and housing structure), particularly for low-income residents, which contributes to global studies on the advancement of energy-efficient behaviour and products and provides insight for policymakers in Bangladesh and other developing economies (Yang and Zhao 2015; Uddin 2018; Debnath *et al.,* 2019; Debnath *et al.,* 2020; Uddin *et al.,* 2021).

All studies (including a variety of factors and intervention approaches) have demonstrated that a variety of factors can have a significant impact on low-income residents' comfort and energy conservation behaviours. This complicates the evaluation of the effect of specific contextual factors (e.g., income, household structure) on slum dwellers who are reliant on existing research. This exhaustive study aims to dissect the unresolved effect of slum dwellers' contextual factors on their energy conservation behaviour.

METHODOLOGY

This study is based on a mixed-method approach such as face-to-face interviews as well as paper-based survey data. The cluster method is implemented for the categorization of slum dwellers.

Study location, housing types, and economic condition

Chittagong, which covers an area of 2510 km2 and is 29 meters above mean sea level, has a population of 2.59 million and is a large port city on Bangladesh's south-eastern coast. May to October is the summer and rainy season, which is cloudy, warm, and wet. A slew of social and environmental issues have harmed Chittagong's port city as a result of the growth of slums, which are frequently criticized for their unplanned urbanization. The employment landscape in a slum is quite different and complex in this case.

The empirical data for this case study were gathered through a scheduled interview in three slum areas of Chittagong, Bangladesh. The study was conducted between May and June 2020, during the summer months. Occupants from 54 slums with varying income levels were surveyed (BDT 5000 - BDT 13000). Throughout the respondent's housing arrangements, Jhupri, Tong, Chai, Tin-Shed, and Semi-Pucca structures are used.

Data sample and measurement

Fifty-four (Total 70) valid slum dwellers from three different categories (e.g., housing type/monthly income) were enlisted for a two-way ANOVA test using the semi-structured interview-based survey approach. Additionally, three categories of housing type and income level were considered: housing type I (Juphri), housing type II (wooden/bamboo), and housing type III (brick wall/tin); and income groups 1 (BDT 5000-7000), income group 2 (BDT 7000-9000), and income group 3 (> BDT 9000). The authors do not wish to disclose the exact location of the slum for data security reasons. Typically, dwellers were given an information sheet outlining the study's purpose and objective. Meanwhile, consent was obtained from slum dwellers using a standard consent form. All residents were between the ages of 15 and 70. The data collection period has been extended from 1st May to 30th June 2020 to make it more convenient for residents.

The entire research process has been divided into several stages (Fig 1). To begin, slum dwellers were questioned about their current energy consumption practices (lighting and fan control) and any known energy-efficient behaviours. This data would be used to assist in determining which behaviours and actions to emphasize throughout the program. Second, an energy-saving awareness campaign (e.g., oral communication/leaflet) has been launched, followed by a survey to determine whether people are already conserving energy. Additionally, target residents are informed about actions and suggestions that are superior to or more important than the current approach. Typical actions and suggestions include the following: use natural light rather than electric light; turn off lights and ceiling fans when leaving the house; ensure that window or floor vents are not blocked by furniture or other obstructions that prevent natural air circulation; and so on.

Thirdly, collecting a monthly energy bill that serves as a baseline for subsequent evaluation and comparison. Typically, authors compare responses to questions about energy consumption behaviours before and after the campaign to determine the effectiveness of the campaign/intervention in modifying slum dwellers' values and

habits. In this case, data were analysed primarily using a two-way variance. Statistically significant findings were defined as those with a p0.05.

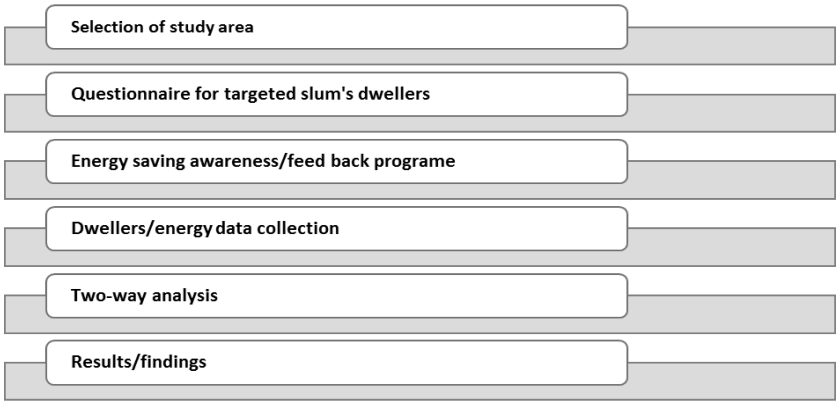

Fig 1: Schematic representation of research approach

RESULTS AND DISCUSSION

Descriptive statistics

The detailed descriptive statistics are presented in Table 1. According to these statistics, energy consumption was slightly higher in Type II (Wooden/Bamboo) houses prior to the intervention/campaign, but significantly higher in Type III (Brick wall/Tin) houses following the intervention campaign. Additionally, Type I (Juphri) houses consumed the least energy both before and after the intervention. Following the intervention, energy consumption was significantly reduced ($p = 0.014$). (Table 2). However, there were no significant interactions between housing type or monthly income and energy consumption for these selected slum dwellers before and after the interventions (Table 2). Similarly, no significant differences in energy consumption were observed between three types of housing or three income groups ($p>0.05$) (Table 3).

Table 1: Descriptive data

Housing	Income Group	Energy Consumption (Pre) Mean (SD)	Energy Consumption (Post) Mean (SD)
Type I	BDT 5000 – 7000	67.34 (12.28)	63.08 (11.24)
Type II	BDT 7000 – 9000	67.34 (12.28)	65.71 (14.04)
Type III	> BDT 9000	67.34 (12.28)	65.92 (11.49)
All		67.34 (12.28)	64.68 (12.29)

Table 2: Comparison of energy consumption before and after intervention

Variables	Type III Sum of Squares	df	Mean Squares	F	p
Energy consumption (Pre vs Post)	79.249	1	79.249	6.513	0.014*
Energy consumption * Housing (Type I vs II vs III)	42.903	2	21.451	1.763	0.183
Energy consumption * Income (Low vs Moderate vs High)	35.711	2	17.856	1.467	0.241
Energy consumption * Housing * Income	8.015	4	2.004	0.165	0.955

*Statistically significant at $p<0.05$

Table 3: Comparison of energy consumption between three housing type or three income group

Variables	Type III Sum of Squares	df	Mean Squares	F	p
Housing (Type I vs II vs III)	304.859	2	152.429	0.514	0.601
Income (Low vs Moderate vs High)	1193.309	2	596.655	2.012	0.146
Housing * Income	823.275	4	205.819	0.694	0.600

Effect of intervention/campaign

It is established that human behaviour plays a significant role in energy consumption, and previous research on various intervention strategies to change individuals' behaviours demonstrates beneficial approaches to sustainable development. To maximize the benefits of progress, an intervention should be conducted with a thorough understanding of the human behaviour that is to be changed or transformed, as well as the factors that influence this behaviour. Although this study demonstrated significant energy savings across all classes of dwellers (as illustrated in Fig 2) because of the campaign/intervention system implemented for slum dwellers in Chittagong, Bangladesh, much more needs to be understood about the success of intervention strategies for energy conservation behaviour.

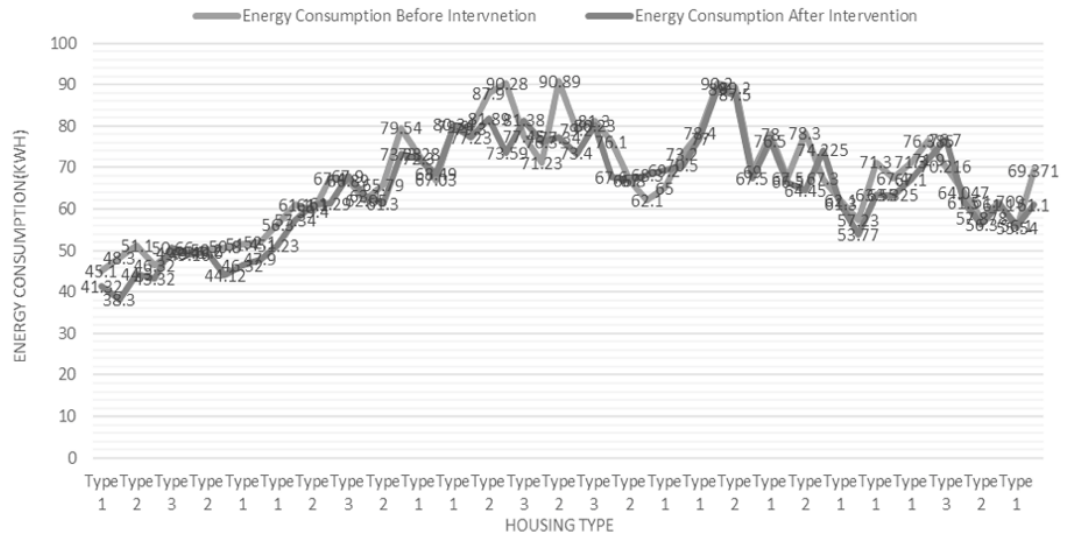

Fig 2: Effect of overall energy consumption before and after the intervention/campaign (All types)

Drive innovation and boost research to deepen energy conservation behaviour

This study approaches energy conservation from a unique perspective by emphasizing low-income residents' perspectives, in response to criticism of conservation factors that ignore residents' actual energy use (Patterson 1996). This is because it appears as though maintaining the quality of energy input to end users is critical to the overall energy efficiency of slums. For example, a low-quality energy input, such as insufficient cooling in an indoor space, will exacerbate the slum dweller's discomfort, resulting in increased control over his or her thermal environment. An example of this type of control is operating a personal fan, which not only assists in regaining occupant comfort but also results in additional energy consumption. This behaviour, induced by user manipulation of the built environment, is a classic example of a rebound effect that works against slum energy conservation, regardless of the

mechanical systems' high efficiency (Lee 2013). Additionally, technology alone will not achieve slum dwellers' energy conservation goals.

Occupants and their energy-related behaviour in houses should be commended for their efforts to improve energy performance. Despite numerous studies on the relationship between occupant behaviour and housing energy performance, our understanding of occupant behaviour and its role in overall energy performance remains complex, unclear, and contradictory. Along these lines, greater emphasis should be placed on incorporating residents' fundamental characteristics into the development of energy strategies. For example, to improve existing energy consumption, certain intervention systems, such as building layout and information programs for tenants or residents, must be considered. Additionally, the interventions examined include the dissemination of information, feedback, and incentives, all of which aim to alter individuals' knowledge and perceptions about energy conservation activities.

CONCLUSIONS

By examining a variety of contextual factors, this study fills a research gap in the literature on housing types, economic conditions, and slum dweller behaviour by recognizing their unmatched influence on energy-efficient behavioural trends. The study used a semi-structured interview-based survey and a two-way ANOVA test to elicit the most efficient energy consumption profiles following the implementation of an energy awareness program. The data were analysed and classified according to housing structure and economic status using a standard descriptive statistical analysis. Although the study found no significant effect ($p>0.05$) on the housing types and economic conditions of slum dwellers, it did discover a significant reduction in energy consumption following the intervention ($p = 0.014$). Additionally, the study discovered that slum dwellers' attitudes and social norms are significant drivers of changes in or reductions in energy consumption patterns following the intervention. In this context, attitude refers to a dweller's belief about a behaviour they are aware of and believe will benefit them in the long run, whereas social norm refers to the social desirability or acceptability of slum dwellers' behaviours.

However, because typical dweller behaviour and comfort are more complex factors than other available factors affecting the energy performance of low-income housing, they require more comprehensive data and technical expertise. If this complication and other complex issues relating to the configuration of indoor systems, structures, social, and economic issues are not adequately addressed, the performance of total energy consumption may suffer. Thus, this study contributes significantly to the global body of knowledge about the contextual factors affecting slum dwellers' energy consumption by elucidating the relationships between housing types and economic conditions. It may be more useful for quickly identifying barriers that require serious intervention to facilitate the adoption of sustainable housing technologies in developing countries.

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REFERENCES

Azar, A and Al Ansari, H (2017) Multilayer agent-based modelling and social network framework to evaluate energy feedback methods for groups of buildings, *Journal of Computing in Civil Engineering*, **31**(4).

Bardhan, R, Debnath, R, Jana, A and Norford, L K (2018) Investigating the association of healthcare-seeking behaviour with the freshness of indoor spaces in low-income tenement housing in Mumbai, *Habitat International*, **71**, 156-168.

Bhide, A and Monroy, C R (2011) Energy poverty: A special focus on energy poverty in India and renewable energy technologies, *Renewable and Sustainable Energy Reviews*, **15**(2), 1057-1066.

Bisu, D Y, Kuhe, A and Iortyer, H A (2016) Urban household cooking energy choice: An example of Bauchi metropolis, *Nigeria Energy, Sustainability and Society*, **6**(15), 1-12.

Bosseboeuf, D (2015) *Energy Efficiency Trends and Policies in the Household and Tertiary Sectors: An Analysis Based on the ODYSSEE and MURE Databases*, Brussels: European Union.

Debnath, K B, Jenkins, D P, Patidar, S and Peacock, A D (2020) Understanding residential occupant cooling behaviour through electricity consumption in warm-humid climate, *Buildings*, **10**, 78.

Debnath, R, Bardhan, R and Sunikka-Blank, M (2019a) Discomfort and distress in slum rehabilitation: Investigating a rebound phenomenon using a backcasting approach, *Habitat International*, **87**, 75-90.

Debnath, R, Bardhan, R and Sunikka-Blank, M (2019b) How does slum rehabilitation influence appliance ownership? A structural model of non-income drivers, *Energy Policy*, **132**, 418-428.

Elsharkawy, H and Rutherford, P (2015) Retrofitting social housing in the UK: Home energy use and performance in a pre-Community Energy Saving Programme (CESP), *Energy and Buildings*, **88**, 25-33.

Faruqui, A, Sergici, S and Sharif, A (2010) The impact of informational feedback on energy consumption - A survey of the experimental evidence, *Energy*, **35**, 1598-1608.

Gillingham, K, Newell, R and Palmer, K (2006) Energy efficiency policies: A retrospective examination, *Annual Review of Environment and Resources*, **31**, 161-192.

Höök, M and Tang, X (2013) Depletion of fossil fuels and anthropogenic climate change - A review, *Energy Policy*, **52**, 797-809.

Kabir, E, Kim, K H and Szulejko, J E (2017) Social impacts of solar home systems in rural areas: A case study in Bangladesh, *Energies*, **10**(1), 1615.

Kowsari, R and Zerriffi, H (2011) Three-dimensional energy profile: A conceptual framework for assessing household energy use, *Energy Policy*, **39**, 7505-7517.

Devi, P and Palaniappan, S (2014) A case study on life cycle energy use of residential building in Southern India, *Energy and Buildings*, **80**, 247-259.

Lee, Y (2013) *Modelling Multiple Occupant Behaviours in Buildings for Increased Simulation Accuracy: An Agent-Based Modelling Approach,* PhD Thesis, University of Pennsylvania.

Oinas-Kukkonen, H and Harjumaa, M (2009) Persuasive systems design: Key issues, process model and system features, *Communications of the Association for Information Systems*, **24**(3), 485-501.

Patterson, M G (1996) What is energy efficiency? Concepts, indicators, and methodological issues, *Energy Policy*, **24**(5), 377-390

Pisello, A L and Asdrubali, F (2014) Human-based energy retrofits in residential buildings: A cost-effective alternative to traditional physical strategies, *Applied Energy*, **133**, 224-235.

Rashid, S F (2009) Strategies to Reduce Exclusion among Populations Living in Urban Slum Settlements in Bangladesh, *Journal of Health, Population and Nutrition*, **27**, 574-586.

Steg, L (2008) Promoting household energy conservation, *Energy Policy*, **36**(12), 4449-4453.

Karim, T F, Lipu, M H and Mahmud, M S (2017) Electricity access improvement using renewable energy and energy efficiency: A case of urban poor area of Dhaka, Bangladesh, *International Journal of Renewable Energy Research*, **7**(3).

Tulsyan, A, Dhaka, S, Mathur, J and Yadav, J V (2013) Potential of energy savings through implementation of energy conservation building code in Jaipur city, India, *Energy and Buildings*, **58**, 123-130.

Uddin, Mn, Wei, H H, Chi, H I and Ni, M (2021a) Influence of occupant behaviour for building energy conservation: A systematic review study of diverse modelling and simulation approach, *Buildings*, **11**, 41.

Uddin, Mn, Wei, H H, Chi, H I and Ni, M (2019) An Inquisition of envelope fabric for building energy performance using prominent BIM-BPS tools - a case study in sub-tropical climate, *In*: IOP Conference Series: Earth and Environmental Science 2019 Oct 1, Macao, China, IOP Publishing (Vol 354, No 1, p 012129).

Uddin, M N, Wei, H H, Chi, H I, Ni, M and Elumalai, P (2021b) Building information modelling (BIM) incorporated green building analysis: An application of local construction materials and sustainable practice in the built environment, *Journal of Building Pathology and Rehabilitation*, **6**, 13.

Uddin, M N (2018) Assessing urban sustainability of slum settlements in Bangladesh: Evidence from Chittagong city, *Journal of Urban Management*, **7**, 32-42.

Wyon, D P, Fang, L, Lagercrantz, L and Fanger, P O (2006) Experimental determination of the limiting criteria for human exposure to low winter humidity indoors (RP-1160), *HVAC&R Research*, **12**, 201-213.

Yang, S and Zhao, D (2015) Do subsidies work better in low-income than in high-income families? Survey on domestic energy-efficient and renewable energy equipment purchase in China, Journal of cleaner production, **108**, 841-851.

Zvingilaite, E and Jacobsen, H K (2015) Heat savings and heat generation technologies: Modelling of residential investment behaviour with local health costs, *Energy Policy*, **77**, 31-45.