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Occupants' Perceptions on Indoor Comfort as a Key Factor in Residential Energy Use.

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Abstract
Ensuring that Ghana accomplishes an appropriate level of energy efficiency is an inevitably urgent issue considering the recurrent energy challenges since the 1990s, the continuous energy crisis since 2010, as well as the rapid rate of deterioration in global warming. Notwithstanding the major role building occupants play in energy consumption, assessing energy efficiency in Ghanaian buildings has mostly been by computer simulations and calculations without factoring their perceptions. This study examined the extent to which the perceptions of residential building occupants on indoor comfort, could impact their electric energy-related behaviours in the homes they live in. An energy conscious "occupants factor" alone could result in between 20% and 50% energy savings. An extensive literature review was conducted on the key concepts and relevant items. The concepts of Perception on Indoor Comfort Based on Building Design (POICBOBD) and Perception on Energy Efficiency Behaviors (POEEB) were used for the study. Residential occupants selected purposively responded to 112 questionnaires. The frequencies and means of the responses were analyzed with Microsoft Excel. Relative Importance Index was used to rank the selected items. SPSS Spearson's rank correlation was also used to establish the relationship between the two concepts and the results showed a strong positive correlation (r=1.000, p=0.01). POICBOBD, therefore, has a significant impact on POEEB and hence likely to affect electric-energy usage in residential homes. This study concludes that since residential homes could act as strong stimuli for electric energy-related behaviours, building occupants must consult architects to design and retrofit their homes, who must also continuously update their knowledge on contemporary systems. Finally, there is the need to develop a comprehensive sensitization of building occupants on energy efficiency measures in order to ensure sustainable behavioural patterns in Ghanaian residential homes.

Keywords
Building design, Occupants' perceptions, Energy wastage, Energy-related behaviours, Residential homes

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1. Introduction

Buildings globally are accountable for about 40% of energy consumption [1], responsible for significant wastewater generation in the world and exhausting the world's water resources [2] as well as a major factor causing climate change. Buildings and their demand for energy are major factors deteriorating the environment and hence the need for an immediate downward review of occupants' consumption of electric energy in buildings. At the centre of residential energy consumption are humans who require energy to be able to perform the majority of their activities within buildings in contemporary times. From research works conducted by [4] and [5], about 90% of the time of the modern person is spent indoors.

From the foregoing, building designers and all built environment professionals must ensure that buildings offer occupants the required indoor environmental quality through natural ventilation and lighting [6], [7]. This is critical in that, building occupants are the key end users of buildings and hence their needs, dependent on electric energy, in the indoor space must be met [8, 9, 10]. This is in the light of the fact that humans in buildings will adopt all possible means of achieving comfort with a higher indoor air quality, which ultimately influences the energy consumption levels of buildings. It was also emphasized that these situations lead to an increment in electric energy consumption levels due to the dependence on electric energy [9]. The role of residential building

designs cannot, therefore, be overemphasized considering their major impact on energy usage of buildings.

The incredible deteriorating nature of energy consumption on the environment makes it very urgent to ensure electric energy efficiency in the world. The extensive negative effects of buildings on the environment worldwide in recent years have caused critical issues like EE and climate change (CC) to be given much prominence [11]. When an energy product is able to reduce the amount of energy consumed per unit of its output, whiles maintaining as well as improving the service it provides to users, it is considered as being an efficient product [12]. Thus, the ultimate goal of energy efficiency in buildings is not an attempt to punish or deprive occupants of their comfort but rather to ensure that the energy used by buildings and its systems are worth being exhausted. This point was further emphasized by [13] who argued that energy efficiency is maintained in a building when all measures used in controlling the amount of energy the building consumes does not end up compromising the designed performance of the building. This is very important in that, as the energy buildings use to keep on increasing, there will be a corresponding increase in the greenhouse gas (GHG) emissions levels globally, which will ultimately worsen the already existing global warming [14].

Considering the major impact of energy consumption on the environment globally, efforts must be put in place to facilitate a reduction in the number of energy buildings consume. For this process to be successful, there is the need to clearly identify the key factors that determine energy usage in buildings and tackle them. Existing studies have isolated the following three factors, which need major focus in reducing energy consumption in buildings; i) design of buildings; ii) building services and energy systems, and iii) occupants behaviour [15,16]. They argued that the integration of passive design with active design and behavioural patterns of building occupants were significant in ensuring efficient use of electric energy in buildings through the building services and energy systems.

This study, therefore, examined the extent to which the perceptions of residential building occupants on indoor comfort, impact their electric energy related behavioural patterns in residential homes. The interaction between building occupants and the buildings they live in, with regards to indoor environmental quality, was, therefore, the focus of the study.

1.1 Residential sector energy situation in Ghana

This section focused on the current state of the Ghanaian residential energy sector. The residential sector in Ghana is accountable for 32% of the total electric energy supplied. However, the residential sector experiences 30% of end-use wastage and this worsens the existing energy supply deficit [17]. Coupled with this is the fact that Ghana has an annual housing deficit of 170,000 units [18]. The consequence of these on energy is that, whilst developing solutions to address the energy deficit, meeting the demand for housing will increase the energy demand and may further deepen the country's electric energy deficits. One way of meeting these challenges with energy consumption is to move away from energy conservation to the efficient use of energy in our homes in order to ensure energy sustainability. In research works done by [19, 20], they maintained that energy usage in buildings is significantly dependent on the electric energy based technologies, systems and services that have been installed in them. There have been recent rising trends in electric energy demand with the residential sector in Ghana. For instance, the residential demand for electricity rose from 24% to 40% from 2005 to 2010 [17]. From 2005 to 2014 the demand for electricity in the residential sector had a 60-percentage increment [21]. This is a probable case of a rapid increase in the demand of electric energy from the residential sector and considering the rate of urbanization and changes in a modern lifestyle where building occupants are becoming increasingly sophisticated and educated leading to an increase in the number and types of household appliances they acquire for their homes. This trend is expected to increase within the next decade and hence requires comprehensive strategies targeted at reducing electric energy wastage in residential homes. Thus, whiles improvements in appliances energy efficiency are advancing significantly, occupants are also wasting the energy.

1.2 Building design and building energy usage

Considering the significant impact of building the design on energy usage in homes, there is a redirection in the way architects process building designs towards having buildings that are EE. This is in the light of the rising awareness and advocacy on the devastating impact of global energy use on climate change with global warming being a major worry [9, 10]. They indicated that this paradigm shift in building design and construction is a step in the right direction towards EE and energy security (ES). An energy efficient building is achieved through a combination of the complexities of the entire processes of building by the team of professionals handling the project. This is done bearing in mind the fact that; a diligent execution of the processes can ensure buildings that use 30% less of energy [22]. He further maintained that a major step to energy efficiency in buildings is to have an envelope that prevents heat buildup and hence reduce the need for mechanical means of ensuring wellbeing in the building.

The rising demand for electric energy in buildings, therefore, calls for sustainable buildings which satisfy the present needs as well as maintaining an environment for

future occupants that is of the same or better quality. However, in a study on students' perceptions of sustainability, he argued that there are minimum awareness levels and appreciation of sustainable buildings for building users and hence one of the major reasons why the concept has not been well embraced by occupants [23]. In another research where a basic school, which had been certified by Leadership in Energy and Environmental Design (LEED), was assessed, he concluded that occupants of the building had misconceptions about sustainable buildings as being cold and not visually appealing. These misunderstandings about energy efficiency in buildings are a worrying situation. This is because the occupant is the end user of the building product and hence their consciousness about energy efficiency will go a long way in ensuring that electric energy wastage in residential homes is reduced. This could be achieved through their decisions on who design their homes (architect) and type of electric energy based appliances and systems they acquire and use in their homes.

The indoor environmental conditions of a building are most affected by the adoption of strategies in relation to energy efficiency [25] and this according to [26] when well implemented can offer occupants of the buildings with an improved comfortable environment. Notwithstanding the positive aspects of energy efficient buildings, they could equally be responsible for thermal distress in building [27]. This according to [28] and [29] is due to the fact that, energy-efficient buildings are usually predominantly ventilated through natural means and hence the indoor air temperature is mostly influenced by the outdoor air temperature. They further argued that this would make the indoor environment very hot in summer, which could make occupants thermally uncomfortable within the indoor space. From research works conducted by [30, 31, 10] they argued that, even though these challenges exist with sustainable building designs, considerable number of research works also confirm that sustainable buildings rather offer a higher level of comfort for building occupants by providing them generally with a better indoor environmental quality as compared with the conservative building concepts. It is, therefore, the right direction for developing countries including Ghana to adopt in the attempt to reduce the level of energy buildings consume. The energy consumption rate of buildings is highly dependent on how the building is designed and constructed as well as the integration of its systems [32]. This means that one of the most initial and essential measures for tackling the increasing nature of energy consumption in the residential sector is to focus on the building and its systems, and Ghana is no exception. Additionally, this calls for a critical look at buildings that exist now, through improvements in the areas of repairs, maintenance and making upgrades in EE (energy retrofitting), as well as new constructions if any success is to be achieved in reducing energy wastage.

Interconnected elements like; (i) the building's purpose and usage; (ii) weather type and position; (iii) design and materials used for construction; (iv) energy source and demand and supply level of the energy; and (v) building occupants behaviors and financial status; are some of the major factors that influence how much energy a building consumes during the running of the facility [13]. The design of buildings, therefore, plays a major role in the perceived energy efficiency habits of residential occupants in Ghana. Other research works also emphasizes the role of i) design of buildings; ii) occupant habits in buildings; and iii) the building systems and services, as major drivers of electric energy usage in buildings and hence the energy efficiency level of buildings [16, 33].

Building designs of residential homes, therefore, affect the comfort levels as well as the electric energy related habits of occupants, which eventually influence how efficiently they use electric energy in the buildings. A research conducted by [34] supports the need to assess the perceptions of building occupants with regards to their experience within the design. The trend of the questions should focus the consciousness of the building occupants on the drivers of residential energy use and inculcate in them the effect of the building design on their energy-related habits within the indoor space.

1.3 Energy Efficient building design and perception theories

A study into occupants' energy-related behaviours maintained that there was the need for explicit analysis on the relationship between energy efficiency and values as well as occupants' behaviour since there are still significant grey areas. Such works will enhance better energy-related attitudes in users of buildings [35]. Considering the major role building occupants play in energy usage of buildings, there is the urgent need for building industry professionals advocating for energy efficiency to identify and appreciate the perceptions of occupants with regards to energy efficiency since that will go a long way in ensuring energy security globally [36, 37]. Though significant literature exists in user perceptions in the area of product marketing, not much has been conducted with regards to designing of buildings as well as its construction [5, 38]. Even though they agree that some works in the area of user perceptions in buildings have been done on post-occupancy assessment of well-being, these were different from what occupants perceive as an energy efficient design based on how the building design influenced their energy-related habits in an attempt to achieve environmental comfort indoors. In that direction, such research works should have the following three key themes on human comfort in a given space; i) subjectivity nature of comfort; ii) the existence of desirable and non-desirable emotions of

occupants, and iii) judgment of comfort being a global concept [39, 40].

The level of perception, either negative or positive, on energy efficiency in residential homes, plays a major role in the acceptability of building occupants with energy efficiency measures as well as their commitment in ensuring that buildings meet their designed and expected energy performance levels. The theories of "Schema Congruity; Stimulus Organism Response (S-O-R model); and Confidence and Compromise" as used to assess green (energy efficient) building occupant habit for marketing purposes further emphasizes the need to factor the perceptions of occupants on EE. Studies conducted by [41, 42], argue that S-O-R model usage indicated that the behavioural patterns of users were significantly affected by their environmental conditions, which was a stimulus to the occupants who have to decide on how to respond to the locational setting.

From the viewpoint of [43], the theories of Confidence and Compromise were very fundamental in ensuring the patronage of end users to a sustainable product. Thus, opting for an energy efficient design means making a compromise not to go for a conventional building design and that becomes more emphatic when the level of confidence by the building occupant about the concept is high. This is very important considering the recurrent energy crisis with the associated load management programs as well as the need to ensure energy security in Ghana [44]. The aim of this study was to examine the extent to which the perceptions of residential building occupants on indoor comfort impacts their electric energy related behavioural patterns in residential homes in Ghana.

2. Methodology

The study used the quantitative method of inquiries in examining the effect of building occupants' perceptions with regards to indoor environmental comfort on energy efficient behaviours in Ghanaian residential homes. Structured questionnaires surveys were used in collecting data on the viewpoints of 112 residential occupants who were purposively selected. This was to evaluate their level of consciousness on how the design of the buildings they live in affects their electric-energy related behaviours regarding their personal experiences. Extensive literature was also reviewed on all the related issues to establish the current situation as well as develop the items to be used for the two key selected concepts namely; i) Perception on Energy Efficiency Behaviors (POEEB) and Perception of Indoor Comfort Based on Building Design (POICBOBD). The questionnaire was structured into three parts: part one consisted of the demographic data, part two was on the Perception on Energy Efficiency Behaviors (POEEB), and part three focused on the Perception on Indoor Comfort Based on Building Design (POICBOBD).

The research used these concepts for assessing how the perception of indoor comfort influence the EE behaviours of building occupants in residential homes based on the building designs. The construct of POEEB considered the actions of residential occupants, due to comfort conditions indoors, with regards to being efficient with electric-energy. The concept of POICBOBD also focused on residential occupants being able to identify their immediate indoor environment as stimuli on their electric-energy related behaviours.

The measurements of the concepts were weighed based on the Likert scale of Strongly Agree, Agree, Moderate/ Neutral, Disagree and Strongly Disagree. They were analyzed based on the means and frequencies of the answers from respondents with Microsoft Excel software and SPSS. It ranged from 1 representing strongly disagree and meaning a lower user perception, with 5 representing strongly agree and meaning a higher user perception. Likert-type or frequency scales used fixed choice response formats and were designed to measure attitudes or opinions of the users [46, 47]. The values were then scored as indicated in Table 1. Determination of these values was based on the formula of Gap width = Range/ group number. The Gap width was therefore determined as = 4/5= 0.8. The research developed the score range in Table 1, to determine whether a variable meets the mean score of the study or not. The research further used Relative Importance Index (RII) method to analyze the data received in-terms of their relative importance of; i) the factors that determine perceptions of energy efficiency (POEEB); and ii) perception of building design POICBOBD).

$RII = \Sigma(W1 + W2 + W3....Wh)/\mathrm{A} \times \mathrm{N}$. Where W = weights given to each variable by the respondents and ranged from 1 to 5; where '1' strongly disagrees and '5' is strongly agree; and A = the highest weight (that is 5 in this research), and N = total number of respondents.

Table 1. Gap widths of Likert scale/ score for POEE and POBD

ITEM	ITEM DESCRIPTION	SCORE
1	Strongly acceptable	4.21-5.00
2	Acceptable	3.41-4.20
3	Moderate/ Neutral	2.61-3.40
4	Unacceptable	1.81-2.60
5	Strongly unacceptable	1.00-1.8

When the mean value is $\leq$ 2.61 the quality is "unacceptable"; if the value is $\rangle$ 3.40 the quality is "acceptable".

3. Findings

3.1 Demographic results of respondents

The type of respondents offers the opportunity to contextualize the findings from the study. Knowing the general information of the respondents of a study is very critical in order to fully understand a research [48]. This research, therefore, used sex, age group, educational background, marital status as well as the occupational status of the respondents as the key variables. The survey consisted of 112 questionnaires completed by purposively selected residential building occupants located in the three climatic belts of Ghana. Accra (coastal belt) with 42 respondents, Kumasi (forest belt) with 47 respondents and Tamale (savannah belt) with 23 respondents was the selected cities for the study. Out of the total respondents, 17.9% were female with 82.1% being male. 60.7% of the respondents were in the 30 to 39 years range, 14.3% in the 40 to 49 age group. The 20 to 29 age group also had 14.3, whereas the 50-59 age groups had 7.1%. 3.6% of the respondents were in the 60 years and above category. This is very critical in that, the majority of the respondents were matured who are more likely to ensure and facilitate a positive impact on guaranteeing energy efficiency in their homes. 83.4% of the respondents were tertiary level graduates whereas the remaining 16.6% from the vocational/ technical category. 35.7% of the respondents were single with the remaining 64.3% of the respondents being married. 82.9% of the respondents were employed whereas 7.1% were students. With regards to their occupation, 89.3% of the respondents were in the built environment profession with 10.7% being in the others category. In that regards, their high consciousness levels offer the potential for effective implementation of EE options in the building industry in Ghana as posited by [43]. Impliedly, this will make them opt for EE in the design and construction of buildings.

3.2 Discussions of POEEB

Perceptions of residential building occupants on energy efficiency behaviours play a major role in ensuring efficient use of electric-energy in households as argued by [36, 37]. The occupants' perceptions were therefore examined on EE behaviours, primarily in terms of the general view as well as sensorial impacts on them and findings have been presented in Table 2 as proposed with regards to the key components of such an inquiry [39, 40]. The first column in Table 2 focused on the key variables used under the concept. The second column was the analysis of the Likert weights chosen by the respondents. The next column had the sum of the various weights score. This was followed by the fourth column, which considered the frequencies of respondents for each of the variables. The next column dealt with the mean values of the responses for the variables. Next to that is the column for the Relative Importance Index (RII), which presented the values for the importance of the variables whiles the last column presented the rankings (positions) of the variables based on the results from the RII.

The results of the overall computation of the mean value of the respondents for POEEB was 4.1381 as shown in Table 2 and hence the construct of POEEB was considered as acceptable, based on the gap width score shown in Table 1. From the five-point Likert responses, the Relative Importance Index (RII) produced values ranging from 0.56 to 1, as shown in Table 2. This range, therefore, indicates a strong level of importance for all the variables used under the category as well as a positive sign of high consciousness levels of the building occupants on EE based on the criteria indicated by [51]. He emphasized that when the figure is above 0.50 it indicates a significant relationship and rating of the construct. Within the POEEB category, (item no. 2.4) "I am aware that the use of air-conditioning systems in the rooms require airtight windows" recorded the highest mean score of 5.0 with RII value of 1.0, implying a 100% consciousness level of the respondents on the use of air conditioners. This suggests a positive attitude of occupants in the area of air-conditioning usage.

Even though the mean score for POEEB was acceptable, within the category (item no. 2.6), "the children (5-17 years) in my home are very observant towards energy consumption at home" recorded 2.82 as the mean score value. This mean value was just above the lowest score value of 2.61, in the "moderate category" based on Table 1 and this confirms the findings from a study on students' awareness levels by [23]. This study suggested the urgent need for curriculum change to factor EE education for students. Impliedly, this study also recommends the need for more education (formal and informal) of children (5-17 years), on using energy efficiently. This could be part of the academic curriculum for schools targeted at improving EE awareness levels in students. There is also the need to continue the general sensitization of all occupants to ensure higher-level energy efficiency in residential homes. This will ultimately reduce Residential Homes Electric Energy Wastage (RHEEW) in Ghana.

Table 2. Assessment of POEEB

PERCEPTION ON ENERGY EFFICIENCY	Weighting of factors										$\sum(W)$	$\sum(F)$	Mean	RII	Rank
	5	n	4	n	3	n	2	n	1	n					
2.1 I switch off all the lights in my home when there is daylight.	68	340	16	64	20	60	4	8	4	4	476	112	4.25	0.85	7^{th}
2.2 I am the person who ensures that the lights in my home are switched off when no one is using them.	76	380	12	48	8	24	12	24	4	4	480	112	4.2857	0.86	6^{th}
2.3 I am the person who ensures that the fans in my home are switched off when no one is using them.	88	440	12	48	0	0	8	16	4	4	508	112	4.5357	0.91	4^{th}
2.4 I am aware that the use of air-conditioning systems in the rooms requires airtight windows.	112	560	0	0	0	0	0	0	0	0	560	112	5	1	1^{st}
2.5 I am aware that without user awareness on electrical energy consumption, there will be electricity wastage in my home.	88	440	20	80	4	12	0	0	0	0	532	112	4.75	0.95	2^{nd}
2.6 The children (5-17 years) in my home are very observant towards energy consumption at home.	12	60	24	96	24	72	36	72	16	16	316	112	2.8214	0.56	12^{th}
2.7 The elderly (18 years and above) in my home are observant towards energy consumption at home.	32	160	48	192	8	24	20	40	4	4	420	112	3.75	0.75	9^{th}
2.8 We should not use electric lighting in our home when we can see well in the daylight.	100	500	4	16	4	12	0	0	4	4	532	112	4.75	0.95	2^{nd}
2.9 We should not switch on electric fans in our home when we are outdoors.	92	460	8	32	4	12	4	8	4	4	516	112	4.6071	0.92	3^{rd}
2.10 We should not iron our clothes whiles watching television programs.	28	140	24	96	28	84	12	24	20	20	364	112	3.25	0.65	11^{th}
2.11 I feel that fans should not be switched on anytime I enter my room from outside and my windows are opened with fresh air coming in.	44	220	28	112	20	60	12	24	8	8	424	112	3.7857	0.76	8^{th}
2.12 I feel that air-conditioning systems should only be used in my home when I feel very hot and uncomfortable.	72	360	28	112	8	24	0	0	4	4	500	112	4.4643	0.89	5^{th}
2.13 Anytime I keep my fridge/ freezer door opened, I am wasting energy.	92	460	12	48	0	0	0	0	8	8	516	112	4.6071	0.92	3^{rd}
2.14 Anytime I do not switch off appliances at the socket, but with a remote control, I am wasting energy.	32	160	28	112	36	108	8	16	8	8	404	112	3.6071	0.72	10^{th}
2.15 Anytime I put water in my kettle beyond the maximum limit I am wasting energy.	36	180	32	128	16	48	20	40	8	8	404	112	3.6071	0.72	10^{th}
Average mean													4.1381		

3.3 Discussions of POICBOBD

Occupant's perceptions of comfort levels in their homes significantly affect their commitment to ensuring that buildings energy usage does not deviate from the designed performance as averred by [32, 34]. There was, therefore, the need to evaluate the perceptions of building occupants with regards to their comfort experiences within their residential homes. This is based on the fact that, how buildings are designed, with regards to the following factors; i) natural air flow through the building; ii) admission of daylighting into the building during daytime; iii) heat loads in the building; and iv) noise admission into the building, affect the comfort levels of occupants and subsequent usage of electric energy as contended strongly by [22, 26]. They indicated probable significant reductions in energy use with the implementation of EE strategies in buildings. The columns used in Table 2 were also adopted for Table 3. As shown in Table 3, the questions were asked on how the building occupant perceives the interaction between their homes and themselves. The results of the computation of the mean value of the respondents on their perceptions on building design were 3.757 with RII ranging from 0.61 to 0.93 which suggest a higher awareness level of occupants on the effects of building design on their energy-related behavioural patterns as posited by [51]. Based on the overall mean score value of POICBOBD, it was considered as acceptable with reference to the gap width score in Table 1.

Even though the category scored a higher average value, within the category, the issue concerning occupants experiencing external noise indoor was ranked last (13th position) with RII of 0.61. Though the score is within the moderate category, with regards to Table 1, there is still need for building designers to comprehensively look at how to reduce the extent of admissible noise into residential homes as indicated by [13]. They maintained that buildings are put up for clear purposes and when they are compromised, energy usage could be significantly affected and hence residential areas should be kept as such and not mixed with other noise generating activities (land uses). This will prevent occupants from closing their windows with the aim of cutting off external noise from entering their homes. If not, such actions will ultimately affect natural ventilation in the homes, which will make the occupants adopt mechanical means for comfort. This is a major challenge especially now that a lot of religious centres are springing up drastically within residential enclaves in Ghana. It is worth noting that, the variables in Table 3, from the tenth to twelfth positions in the rankings (3.3, 3.11 and 3.15 respectively in a descending order) were all issues that directly affect the thermal comfort of occupants indoors and hence the need for built environment professionals and architects to ensure that sustainable building designs are built for

residential occupants as proposed by [30, 31, 10]. These authors vigorously argued that when occupants experience thermal distress indoors, it significantly causes a rise in household energy usage, through electric energy based actions to maintain thermal comfort.

3.4 Rank relationship between POEEB and POICBOBD

The research further examined the relationship that existed between POEEB and POICBOBD to provide the degree of how closely the two sets of rankings agree with each other as affirmed by [51]. To do this, the research used Spearman's rank correlation (rho) to assess the first to tenth positions on both rankings and the results have been presented in Table 4. Within Table 4, the first column indicated the type of correlation that was conducted. The next column defined the two concepts that were used for the correlation. The next column captured the nature of the analysis that was conducted and under this circumstance being a 2-tailed test. The fourth column showed results of the correlation between the two variables and POEEB whereas the last column presented results of the correlation between the two concepts and POICBOBD. The findings suggest a strong positive correlation between the two concepts. The results show that there is evidence to suggest that when occupant's perceptions of indoor comfort are higher it positively fosters a higher adoption of energy efficiency behaviours in residential homes in Ghana.

			POEEB	POICBOBD
Spearman's rho	POEEB	Correlation Coefficient	1.000	1.000**
		Sig. (2-tailed)	.	.
		N	10	10
	POICBOBD	Correlation Coefficient	1.000**	1.000
		Sig. (2-tailed)	.	.
		N	10	10

Figure 1. Spearman's rank correlation results between POEEB and POICBOBD

From fig 1, with r = 1.000 and $\rho = 0.01$, it can be concluded that there is a very strong positive relationship between the two variables and this confirms the work of [50]. They emphasized that when the perceptions of indoor comfort by occupants were high, there was a higher probability of exhibiting EE behaviours indoors. The correlation is further indicative of both constructs having average mean scores in the category of "acceptable" as defined in Table 1. The implication of this is that occupants' perceptions of indoor comfort are very relevant in ensuring EE behaviours in homes and this further confirms the findings of [11]. They posited that the perceptions of building occupants were significantly relevant in assessing a building's level of EE.

Table 3. Assessment of POICBOBD

BUILDING DESIGN	Weighting of factors										$\sum(W)$	$\sum(F)$	Mean	RII	Rank
	5	n	4	n	3	n	2	n	1	n					
3.1 I do not feel hot in the mornings (7 am – 11 am) when I am home indoors.	34	170	44	176	20	60	8	16	6	6	428	112	3.821429	0.76	7^{th}
3.2 I feel hot in the afternoons (12 noon – 5 pm) when I am home indoors.	36	180	34	136	28	84	10	20	4	4	424	112	3.785714	0.76	7^{th}
3.3 I feel hot in the evenings (6 pm – 11 pm) when I am home indoors.	12	60	30	120	36	108	30	60	4	4	352	112	3.142857	0.63	12^{th}
3.4 I do not feel hot in the night (12 am – 5 am) when I am home indoors.	32	160	32	128	32	96	12	24	4	4	412	112	3.678571	0.74	8^{th}
3.5 I do not feel damp or sticky in my home throughout the year.	52	260	32	128	16	48	12	24	0	0	460	112	4.107143	0.82	3^{rd}
3.6 The rooms in my home are not always stuffy (difficulty in breathing).	68	340	24	96	12	36	8	16	0	0	488	112	4.357143	0.87	2^{nd}
3.7 I do not sneeze continuously anytime I enter my home.	80	400	24	96	8	24	0	0	0	0	520	112	4.642857	0.93	1^{st}
3.8 My home is not dark in daylight and does not necessitate for artificial lights.	64	320	20	80	8	24	12	24	8	8	456	112	4.071429	0.81	4^{th}
3.9 My home enjoys effective natural ventilation which does not necessitate the use of fans throughout the year.	48	240	28	112	8	24	24	48	4	4	428	112	3.821429	0.76	7^{th}
3.10 I do not feel the sun entering my eye (glare) during sunrise and sunset in my home every day.	48	240	40	160	16	48	0	0	8	8	456	112	4.071429	0.81	4^{th}
3.11 I feel comfortable with the location of the various spaces in my home.	24	120	24	96	28	84	20	40	16	16	356	112	3.178571	0.64	11^{th}
3.12 Too much noise from the outside of the building enters my home.	24	120	20	80	28	84	16	32	24	24	340	112	3.035714	0.61	13^{th}
3.13 I do not close my windows to avoid noise from outside into my home because of ventilation reason.	40	200	32	128	24	72	8	16	8	8	424	112	3.785714	0.76	7^{th}
3.14 I do not have natural day-lighting problem in my home.	36	180	44	176	24	72	0	0	8	8	436	112	3.892857	0.78	6^{th}
3.15 I do not have effective natural ventilation problem in my home.	28	140	24	96	24	72	20	40	16	16	364	112	3.25	0.65	10^{th}
3.16 I do not experience the penetration of environmental noise indoors.	16	80	48	192	16	48	16	32	16	16	368	112	3.285714	0.66	9^{th}
3.17 Even when I feel hot, I prefer closing my windows for visual privacy reasons.	48	240	32	128	16	48	10	20	6	6	442	112	3.946429	0.79	5^{th}
Average Mean													3.7574		

4. Conclusions and recommendations

The design of residential homes plays an integral role in achieving energy efficiency in buildings, which ultimately leads to a significant reduction in electric energy consumption. This is critical, especially for developing countries such as Ghana where energy supply has been a major challenge in recent times. Studies into achieving energy efficiency in buildings have typically been a simulation and calculation-based research with little attention focused on occupant behaviours. This study, therefore, examined the extent to which the perceptions of residential building occupants on indoor comfort impact their electric energy related behavioural patterns in Ghanaian residential homes.

Findings show that notwithstanding the fact that POEEB had an acceptable average score of 4.138, within the category (Table 2), item 2.6, the issue of "the children (5-17 years) in my home are very observant towards energy consumption" (12th position) recorded the lowest RII of 0.56. This was followed by, item 2.10, the issue of ironing whiles watching TV in the (11th position) and with RII of 0.65. Item 2.14, the issue of switching off appliances with the remote control wasting energy and item 2.15, the issue of overfilling kettle wasting energy all had RII of 0.72. These results suggest that majority of occupants are not aware of the habits that cause them to waste significant energy in their home. This calls for a comprehensive program in educating occupants on energy efficient measures and behaviours, probably in the education curriculum as well.

The POICBOBD (Table 3) category scored an acceptable mean score value of 3.757, within the category, item 3.3, the issue concerning occupants experiencing external noise indoors was ranked last (13th position) with RII of 0.61. The issue of noise entering residential homes is very critical considering the new trends in the Ghana where churches are springing up across most residential enclaves. There is, therefore, the need for firmer building codes that will ensure that such developments would not discomfort occupants leading them to adopt all mechanical means possible to achieve comfort indoors. This variable was then followed by item 3.3, the issue concerning occupants feeling hot between 6 pm to 11 pm (12th position) with RII of 0.63. Item 3.11, the issue of occupants feeling comfortable within the various spaces in their homes, then followed (11th position) with RII of 0.64. The issue of occupants not feeling effective natural ventilation in their homes (item 3.15) was in the 10th position with RII of 0.65. All these three variables directly affect the thermal comfort levels of occupants and hence the results suggest that the building designs of the respondents were not fully responsive to the thermal comfort needs of occupants. The implication of this is that they are more likely to adopt all available mechanical means for cooling purposes.

Findings for the relationship between POICBOBD on POEEB also showed that POICBOBD by occupants with $r = 1.000$, has a significant impact on occupant's POEEB and hence can affect how much electric-energy is used in residential homes. The research, therefore, maintains that beyond simulations and calculations are done to predict buildings' energy performance, the perceptions of occupants play a significant role in measuring EE in residential homes. This research critically reveals to building occupants that, their homes could act as strong stimuli for their electric-energy related behaviours and hence the need to consult professional architects for designing and retrofitting their homes. This calls for buildings with passive design measures and efficient building envelop materials and calls for architects and other built environment professionals to continuously update their knowledge about the ever-changing energy efficiency measures that can be employed in contemporary times. Thus, it reiterates the need for developing comprehensive sensitization of building occupants on energy efficiency measures in order to ensure energy efficient behavioural patterns of occupants in residential homes in Ghana.

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