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Impacting Occupants' Socio-demographics on the Housing-Energy Correlations in Apartment Buildings of Mashhad, Iran

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Abstract

Housing energy efficiency depends on a balanced interplay among various aspects dealing with housing architecture, e.g., human, building, environment, and climate. Existing studies have seldom paid comprehensive attention to such interrelationships. Yet this is highly important in apartment residential buildings due to growing popularity of apartments in many cities across the globe. A critical gap is to study the interrelationships between occupants' characteristics, housing features, neighbourhood characteristics, and housing energy performance. This study assesses the correlations between housing physical feature and energy intensity of apartment housing, and the effect of occupants' socio-demographic characteristics on these correlations. Data were gathered from 50 occupants across 20 residential apartment housing buildings in Mashhad, Iran. Correlation test and Non-Parametric Independent-samples Mann Whitney U test were employed. The findings suggest that age and length of residency determine the choice of housing physical features, and energy intensity. These are the signs of occupants' maturity, experience, stability, and attachment. The findings of the study emphasize the impacts of occupants' demographic characteristics on the correlations between housing physical features and energy intensity. The findings in addition indicate the necessity of information provision especially for younger occupants of apartment housing of Mashhad, through education, training, and a smart informational platform. The provision of information would have significant implications for energy justice and equity. The study is a reminder of a critical informational gap in apartment housing, whereby the occupants are mostly absent during the housing provision procedure.

Keywords: Energy Efficiency; Mass Apartment Housing; Occupants' Socio-Demographic Characteristics; Mashhad; Iran.

1. INTRODUCTION

The housing sector accounts for a significant share of energy consumption across the globe, emphasizing the need for housing energy efficiency (EE) to mitigate the impacts of global warming and climate change. In an attempt to address this, several action plans, e.g., building codes, measures, regulations, technologies, and initiatives (e.g., DCLG, 2010; 2007; DECC, 2010; ABCB, 2020, 2014, DEWHA, 2008b), have been developed.

One critical challenge, however, in improving EE is the lack of attention given to the impacts of the interplay between different aspects, e.g. human, building, environment, and the climate, which may even result in relatively high energy consumption of a house, even if it is built on the basis of sustainability codes and principles (Antonopoulos, et al., 2019; EPA, 2021; Gower, 2021; Orr, 2002; Sari, 2021).

EE at the construction phase may not result in EE at the operation phase because of the impact of occupants' behaviours, which are influenced by their socio-demographic characteristics in conjunction with neighbourhood environmental conditions (Antonopoulos, et al., 2019; Gower, 2021; Orr, 2002, Hearn, et al., 2022). Gower (2021) indicated that the EE at the building scale may not be able to adequately respond to occupants' real needs at the housing unit scale, which could result in energy vulnerability and increased dependency on active energy sources. She believed that this occurred because of their socio-demographic characteristics and the impact of several secondary environmental parameters.

Rashed et al. (2023) stressed the lack of comprehensive sustainability informational platforms as a critical gap in promoting sustainable housing. Providing comprehensive information improves people's knowledge and awareness of the different aspects of housing and hence encourages people to engage in positive decision making and behaviours (Asadpoor, et al., 2021; Asadpoor & Jahanshahi, 2025; Rashed, et al., 2023; Sari, 2021), which in turn can positively influence their quality of life (Ramkissoon, 2023a; 2023b).

A few studies (e.g., Bortolini, et al.; 2022, Mazur, et al., 2022) have conducted multi-criteria analyses of housing energy efficiency (HEE). An emerging gap is the lack of attention given to the human side of the equation and the substantial roles played by people's perceptions and attitudes reflected in their socio-demographic characteristics.

In the present study, we posit that EE in housing is more impactful when the interplay between the physical aspects of housing is considered in alignment with occupants' needs. A potential solution to bridge this gap is to develop a concrete explanation of the interrelationships between the different aspects of housing architecture in a broader term, i.e., occupants' characteristics, building characteristics, environmental characteristics, and climate information, in impacting housing EE.

Urban apartment housing has become popular in several nations, e.g., China, Singapore, and Iran (Biglarie, et al., 2026; European Union, 2025; Ma, et al., 2026; Liahnson, 2025; Ayashm, 2025), which contributes largely to energy consumption. End-users are mostly absent during the housing provision procedure, i.e., planning, design, and construction (Asadpoor and Jusan, 2017; Biglari, et al., 2026; Gower, 2021). There is a need to specifically understand and implement occupants' motivations in housing EE decision-making and action plans by concretely representing the role of these motivations in the interplay between the physical

aspects of housing architecture and housing EE. Mashhad is the second-largest metropolitan city in Iran, and as in many other developing countries with rapid urban growth and severe housing shortages, there has been rapid growth of apartment buildings in recent decades (Biglari, et al., 2026). Several challenges are noted, including inadequate building performance in the operation phase and insufficiencies in meeting occupants' demands, which have led to an increase in the energy consumption of this type of housing (Gholizadeh, et al., 2021; Frouhar & Forouhar, 2020). We use the city of Mashhad as a case study to examine the interplay between the different areas of this housing type, the occupants' characteristics, and energy efficiency.

The present study aims at assessing the impacts of occupants' socio-demographics on the correlations between physical features (building, dwelling units, and neighbourhood) and the energy performance of apartment housing. This is especially beneficial for the representation of occupants' needs, demands, and desires in mass housing and for helping people select different neighbourhood environmental dimensions and buildings characteristics of buildings on the basis of their socio-demographic characteristics in many countries across the globe, e.g., China, India, Iran, and Singapore.

2. LITERATURE REVIEW

An overview of the literature shows that although many energy efficiency (EE) measures have been implemented, overall energy consumption has not been effectively reduced across the globe (e.g., Boloria, 2020; Harris et al., 2008; Thomas et al., 2019). Decker (2018) stressed that partial improvements in EE often result in greater use of services and products or the emergence of new habits and demands (Decker, 2018). Sorrel (2015) indicated that overall EE depends on the development of proper comprehensive and integrated improvements in all aspects of the entire system. Some scholars (e.g., Bertoldi, 2017; Boloria, 2020; Orr, 2002; Thomas et al., 2019) have recommended energy sufficiency and conservation/saving concepts, which depend on the enhancement of all energy-related aspects of the system.

It is necessary to develop a hybrid approach, which is a combination of bottom-up human-centric and top-down techno-centric approaches (Centre for Climate and Energy Solutions (C2ES), 2015; Boloria, 2020; Moser & Uzzell, 2003; Orr, 2002; Ramkissoo et al., 2013a; 2013b). Such a hybrid approach can provide a balanced interplay between all aspects of EE, leading to people's positive perceptions, attitudes, and sense of control and hence promoting their active participation and pro-environmental behaviours (Ajzen, 2011; Goh, Jeevanandam & Jeevanandam, 2021; Ramkissoo, 2023a).

Given the role of mass apartment housing as the main source of energy consumption across several countries as discussed and the role of different aspects of housing architecture, e.g., people's characteristics, building characteristics, and environmental dimensions in the energy performance of housing (Ahvenniemi & Häkkinen, 2020; Antonopoulos, et al., 2019; Asadpoor and Thorpe, 2017; EPA, 2021; Frouhar & Forouhar, 2020; Gholizadeh, et al., 2021), developing such an approach is inevitable for the enhancement of energy consumption in this housing type.

Several countries have developed a wide range of EE action plans, including building codes, regulations, technologies, rules, regulations, measures, and initiatives (e.g., ABCB, 2020, 2014, Bond, 2011; DCLG, 2007; DECC, 2010; Kellet and Jowsey, 2012). There are also several information provision platforms, websites, and rating tools aimed at promoting residential building EE (e.g., SA. GOV., 2017, 2019; Australian Government, 2019; EPA, 2021, DCLG, 2010; DEWHA, 2008b).

The CRCLCL (2016) study indicated that people also hold positive attitudes toward housing EE. Despite these efforts, evidence suggests that there is steady growth in the overall energy consumption of the housing sector (BZE, 2013; Centre for Sustainable Systems, University of Michigan, 2025; DEWHA, 2008a; Kellett & Jowsey, 2012). This is rooted in the current direction of housing development and a lack of connection to households' perceptions and attitudes, deviating their daily life habits, behaviours, and activities (Asadpoor and Thorpe, 2017; BZE, 2013; Decker, 2018; DEWHA, 2008a; Kellet & Jowsey, 2012). Rashed et al. (2023) indicated that the sustainability of the building industry has remained suboptimal due to the lack of a proper information provision platform, which is able to provide timely, low-cost, reliable, easy access, simple, comprehensive, and integrated information. Given this gap, although the housing EE might be technologically and physically achieved, the insufficiencies in responding to occupants' real daily life needs slows down or could even halt energy consumption improvements (Gower, 2021). Although people with different characteristics, e.g., age, gender, marital status, education, job, health condition, and family position, have different needs, they are not able to find a suitable energy-efficient house that is able to meet their energy demands and desires (EPA, 2021; Gower, 2021) and hence this situation seriously impacts people's comfort, health, and well-being (Ramkissoon, 2023b), resulting in inappropriate energy consumption by occupants and the energy performance of the dwelling unit (EPA, 2021).

Therefore, developing more sensitive and profound information provision platforms, i.e., online databases, assessment and decision making tools that make it possible to identify the interplay between the different aspects of housing in a broader and comprehensive way, i.e., occupant, building, and neighbourhood, in impacting HEE is highly essential. Such a platform should help occupants achieve more congruent housing in relation to their perceptions, affordability, demands, and desires (Asadpoor & Jahanshahi, 2025). This platform should be able to assess the congruity of energy-related features with household needs and desires to enhance the energy performance of the unit by improving people's energy consumption habits, behaviours, and activities (Asadpoor and Thorpe, 2017; Asadpoor, et al., 2021).

We now discuss some concrete and tangible pieces of evidence from a few empirical studies conducted on the necessity of understanding the interrelationships between the different aspects that impact HEE.

According to the Paris Agreement (C2ES, 2015), long-term sustainability depends strongly on a blended approach that combines bottom-up flexibility and top-down fixed rules. Orr (2002) suggested that improving technological aspects is just the beginning, and real long-term sustainability depends on improving all aspects of sustainability. He recommended an ecological (earth-centred) approach instead of the current technological approach.

Biloria (2020) also indicated that the integration of techno-centric and human-centric approaches is essential in achieving EE goals. Given the concept of energy equity, Gower (2021) also recommended that to proactively alleviate energy vulnerability, it is necessary to consider all various aspects of energy consumption, e.g., human factors, environmental factors, and building characteristics. Such a comprehensive, hybrid, and proactive approach is necessary for the provision of a balanced interplay between the different aspects, especially in relation to human characteristics. This, in turn, can promote pro-environmental behaviours and hence enhance the overall outcomes of the implemented EE plans by encouraging individuals toward EE behaviours (Ramkissoon et al., 2018; Ramkissoon, 2020b; Ramkissoon et al., 2025).

Such approaches make it possible to combine efficiency and sufficiency concepts (energy conservation/saving/reduction) and hence reduce overall energy use in housing (Harris, et al., 2008, Biloria, 2020). Energy conservation/saving depends mainly on reducing overall energy demand (Harris, 2008), which is rooted in pro-environmental behaviours promoted by the enhancement of people's positive perceptions and attitudes (Ramkissoon et al., 2013b).

From an equity and energy justice perspective, environmental challenges have more serious impacts on at-risk vulnerable people (United States Environmental Protection Agency (EPA), 2021). Hence, paying proper attention to these population groups in the development of sustainability measures has a highly critical role in meeting environmental equity (EPA, 2021). Given the inequitable distribution of environmental challenges in different urban districts, the lack of attention given to the interplay between the different aspects of housing EE has also resulted in serious environmental inequity. For instance, low-income people constitute the most at-risk group and need particular attention in developed HEE plans to help them in achieving proper energy-efficient dwelling units on the basis of their energy needs, demands, and affordability (Gower, 2021).

Sari (2021) stated that some human factors, e.g., information, communication, awareness, and education, have the potential to improve energy consumption behaviours. Asadpoor et al. (2021) stressed that occupants' housing EE perceptions depend on their bioclimatic preferences and sense of control, which impact their perceptions and attitudes toward different energy-related housing attributes. Rashed et al. (2023) indicated that reliable, simple, timely, easy access, and low-cost information is an essential step in promoting housing sustainability.

These studies emphasized the necessity of providing a multi-criteria information platform, especially in relation to occupants' socio-demographic characteristics, as a crucial requirement of HEE. The provision of such a platform depends on a concrete explanation of the interrelationships among occupants' socio-demographic characteristics, physical attributes, energy consumption, and neighbourhood environmental characteristics. This is especially beneficial in mass housing, whereby real occupants are mostly absent during housing provision procedure, possibly do not have a proper level of expertise in EE, and need proper information to select a more suitable dwelling unit on the basis of their socio-demographic characteristics (Asadpoor & Jusan, 2017; Asadpoor, and Jahanshahi, 2025).

Such a database would also provide a suitable platform for housing authorities to enhance housing EE in relation to the needs of different groups of occupants. Such an information

provision would also be beneficial not only for the engagement of occupants in adjusting, modifying, and changing their housing units in relation to their EE needs and demands but also for the enhancement of their energy consumption habits and behaviours by improving their sense of control and pro-environmental behaviours (Ramkissoon, 2022a; b; 2023a; 2023b). It is necessary to examine the interrelationships among the different aspects of mass apartment housing architecture, i.e., people, buildings, and the environment, with an emphasis on the role of occupants' socio-demographics in impacting housing EE.

3. Research Methodology

This study was conducted through a database developed on the basis of an occupant-building profile, which includes respondents' demographic characteristics, a sample set of housing physical features (building, façade, dwelling units), neighbourhood characteristics, and energy intensity (EI) of the dwelling units selected from previous studies (Table 1) (Asadpoor and Jahanshahi, 2025, Biglari, et al., 2026). Energy intensity, which is defined as the energy consumption per square meter in a dwelling unit, was selected as the indicator of the energy performance of the dwelling unit. The EI was measured by identifying the electric power consumed in the hot season (July–August) from the electric bills of the units. The EI in the hot season was selected because of the critical role of the cooling load of housing units in impacting overall electric power consumption, the substantial imbalances in electric power generation, the fossil fuel dependency of electric power generation, and the negative environmental impacts of electric power generation and consumption, e.g., carbon emissions and urban heat islands (UHIs) in Iran (Biglari, et al., 2026).

Table 1: Developed profile of occupants, buildings, neighbourhoods, and EI information

	Aspects	Features
	Occupants' socio-demographic characteristics	Age, Gender, Marital status, Job, Education, Number of Children, Family size, Education, Ownership, Length of residence
	Building physical features	Land size, Yard area, Building area per land size, Building density, Residential built-up area per land size, Number floor, Number of unit, Number of unit per floor, Number of light-passing external wall, Building age
	Façade physical features	Façade width, Façade height, Façade width to height, Façade Main material, Façade main material colour, Façade shape, Façade main material roughness, Façade main material reflectivity, Façade area, Window area
	Dwelling unit physical features	Dwelling unit area, Dwelling unit ventilation, Window area to unit size
	Neighbourhood characteristics	Urban District, green cover percentage in radius of 20 m., Shading on the façade in hot season,
	Dwelling unit EI (hot season)	The energy consumption per square meter of the dwelling unit obtained from electric power energy bill

The reliability of the developed set of physical variables (building, façade, dwelling unit, and neighbourhood) was initially examined through an expert survey via the Likert five-point scaling technique (Field, 2009). This analysis technique was employed to examine the validity of the initially selected physical variables and ensure that the variables are suitable for apartment housing in Mashhad, Iran (Caniato and Gasparella, 2019; Fowler, 2014; Klassen et al., 2012; Koo and Yang, 2025). A total of 28 out of 41 initially invited experts participated in the survey (Table 2). They were invited to express their personal

characteristics, i.e., gender, age, marital status, education, area of expertise, area of job, and years of experience (Table 2). They were then asked to rate the importance of the different physical variables presented in the profile for apartment housing in Mashhad from 1 (very low) to 5 (very high).

Table 2: Socio-demographic characteristics of the experts/professionals

			Area of Expertise			Area of Job		Year of Experience (Year)		
			Architect	Civil	Urbanism	Academic	Industry	<10	10 to 20	>20
1	Gender	Male	9	3	2	2	12	5	7	2
		Female	6	2	3	3	8	4	5	2
2	Age	<45	8	2	3	0	13	8	5	0
		45 to 0 55	4	2	1	0	7	1	6	0
		55 to 65	2	0	1	3	0	0	1	2
		>65	1	1	0	2	0	0	0	2
3	Marital status	Single	4	1	2	1	6	4	2	1
		Married	11	4	3	4	14	5	10	3
4	Education	Bachelor	7	3	2	0	12	8	4	0
		Master	5	1	2	0	8	1	6	1
		PhD.	3	1	1	5	0	0	2	3

The expert survey data were collected, and Cronbach's alpha test was performed to examine the internal consistency among the variables via SPSS software (Costello and Osborne, 2005) (Table 3). The results show excellent internal consistency for the majority of the variables (above 0.9) and good internal consistency for only one variable, i.e. building age (above 0.7) (DeVellis, 2012).

The building-occupant profile of apartment housing in Mashhad was developed as the main database of the study, using all the variables presented in Table 1. The database included data collected from 50 respondents (Table 3) living in 20 buildings and 29 dwelling units located in 2 urban districts of the city, i.e., the city centre and western suburb. In this study, the selected samples were apartment buildings of Mashhad, which at least one of their façades (light passing external walls) are located in the geographical south, and the data related to this façade were considered for the data collection procedure.

Table 3: Socio-demographic characteristics of the respondents

		Count
1	Gender	Male
		Female
2	Age	<25
		25 to 45
		45 to 65
		>65
4	Marital status	Single
		Married
4	Education	Diploma and below
		Bachelor
		Master
		PhD.
5	Family position	Principle occupant
		Spouse
6	Ownership	Owner
		Renter
7	Length of	<5

	Residence	5 to 10	11
		>10	25

The required data for the different variables were gathered from face-to-face surveys, field observations and measurements, city council building certificates and documents, satellite-based measurements, and dwelling units' electric bills (Antonopoulos, et al., 2019; Gower, 2021; Biglari, et al., 2026). The database of the study, which included the collected occupant-building data, was then developed for the subsequent analyses by transferring the information into SPSS (Field, 2009).

This study proposes that specific socio-demographic characteristics of dwellers are significantly associated with their dwelling unit EI in the hot season and this relationship may be attributed to their selection of specific housing physical features. To test these objectives, the elements of the three variables were assessed for significant associations via correlation analysis. These variables' interrelationships allow the identification of specific elements related to socio-demographics and housing physical features that are related to dwelling unit EI in the hot season. The specific socio-demographics of the dwellers that are significantly associated with dwelling unit EI in the hot season are identified first. Then, the physical features associated with dwelling unit EI are identified next. These two sets of correlation information in turn afford further analysis of the specific interrelationships between dwellers' socio-demographic elements, housing physical features and dwelling unit EI in the hot season via the non-parametric independent samples Mann–Whitney U test. The above series of analyses shed light on which socio-demographic characteristics are associated with dwelling unit EI in the hot season (EI) and which physical housing features are integral to their associations.

Given the small sample size (N=50) of the study and non-normal distribution of the features, correlation and non-parametric independent samples Mann–Whitney U tests were selected as suitable analysis techniques for the study (Field, 2009).

4. Results

The correlations between socio-demographics, EI, and housing physical features revealed that only age and length of residency were significantly associated with both EI and housing physical features. Age was correlated with EI at $r(50) = -.47, p < .001$, and length of residency was correlated with EI at $r(50) = -.48, p < .001$ (Table 4). Age and length of residency were significantly correlated with some physical housing features, which are presented in Table 5.

Table 4: Age and length of residency correlations with EI that are significant at cutoff $p < .001^{**}$

Age and Length of residency correlation with EI, cutoff set at $^{**}p < .001$ (n=50)		
Age		
1	EI	$r = -.47^{**}$
Length of residency		
1	EI	$r = -.48^{**}$

Table 5: Age and length of residency correlations with physical housing features that are significant at cut-off $p < .001^{**}$

Age and Length of residency correlation with housing physical features, cutoff set at $^{**}p < .001$ (n=50)		
Age		
1	Green cover percentage in radius of 20 ^m (%)	$r = .467^{**}$
Length of residency		
1	Building density (build-up area/land size)	$r = -.465^{**}$
2	Unit natural ventilation (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high)	$r = .516^{**}$
3	Green cover percentage in radius of 20 ^m (%)	$r = .605^{**}$

The housing physical features that were significantly associated with dwelling unit EI in the hot season are also presented in Table 6.

Table 6: Dwelling unit EI in the hot season correlations with physical housing features that are significant at cut-off $p < .05^{*}$, $p < .001^{**}$

Energy Intensity (EI) correlation with housing physical features that are significant at cut-off $p < .05^{*}$, $p < .001^{**}$ (n=50)		
1	facade main material color (1=very dark, 1.25=dark, 1.5=middle, 1.75=light, 2=very light)	$r = .527^{**}$
2	facade overall shape (1=very concave, 1.25=concave, 1.5=flat, 1.75=convex, 2=very convex)	$r = -.446^{**}$
3	façade main material roughness value (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high)	$r = .296^{*}$, $p = .037$
4	facade main material reflectivity (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high)	$r = -.351^{*}$, $p = .012$
5	land size (m ²)	$r = -.534^{**}$
6	yard area (m ²)	$r = -.649^{**}$
7	building area per land size	$r = .557^{**}$
8	residential built-up area per land size	$r = .394^{**}$
9	building density (build-up area/land size)	$r = .607^{**}$
10	number of facade (open side of building with windows) (n)	$r = -.474^{**}$
11	building age (year)	$r = -.579^{**}$
12	window area (m ²)	$r = -.483^{**}$
13	unit area (m ²)	$r = -.585^{**}$
14	unit natural ventilation (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high)	$r = -.492^{**}$
15	green cover percentage in radius of 20 ^m (%)	$r = -.826^{**}$
16	global horizontal radiation (max hourly)-hot season (Wh/m ²)	$r = -.304^{*}$, $p = .032$
17	shading on the facade-hot season (0=very low, 0.25=low, 0.5=middle, 0.75=high, 1=very high)	$r = -.548^{**}$
18	age (year)	$r = -.474^{**}$
19	ownership (1=owner, 2=renter)	$r = .285^{*}$, $p = .045$
20	Length of residence (year)	$r = -.483^{**}$

Further analyses via non-parametric independent sample Mann–Whitney U tests were conducted to determine whether 1) EI significantly differs according to age and length of residency groups and 2) the physical features reported in Table 5 significantly differ according to age and length of residency groups. The results of these analyses reveal which housing physical features are related to the links found between EI and age, as well as

between EI and length of residency. Age groups were categorized into two groups: low (≥ 51 years old) and high (≤ 52 years old). The length of residency groups were also categorized into two groups: low (≤ 8.6 years) and high (≥ 8.7 years).

Mann–Whitney U test for the effects of age groups and length of residency groups, on energy intensity

Age: Tables 7 and 8 show that there is a significant difference in the energy intensity scores between residents from 51 years of age and below (group 1) and those from 52 years of age and above (group 2) ($p=.011$), with a cut-off at $p<.05$.

The average energy intensity score for residents 51 years old and below (group 1) is 3.02, and the energy intensity score for residents 52 years old and above (group 2) is 2.49.

Table 7: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of EI-hot season (kwh/m ²) is the same across categories of mean 51.	Independent-Samples Mann–Whitney U Test	.011	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 8: Independent-samples Mann–Whitney U test summary

Total N	50
Mann–Whitney U	177.500
Wilcoxon W	430.500
Test Statistic	177.500
Standard Error	51.142
Standardized Test Statistic	-2.552
Asymptotic Sig.(2-sided test)	.011

Length of residency: There was a significant difference in the energy intensity scores between those with a length of residency of 8.6 years and below (group 1) and those with a length of residency of 8.7 years and above (group 2) ($p=.039$) the cut-off at $p<.05$ (Tables 9 and 10).

The average energy intensity score for group (1) is 3.10, and the energy intensity score for group (2) is 2.55.

Table 9: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of EI-hot season (kwh/m ²) is the same across categories of mean 8.6 length residence.	Independent-Samples Mann–Whitney U Test	.039	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 10: Independent-samples Mann–Whitney U test summary

Total N	50
Mann–Whitney U	206.000
Wilcoxon W	531.000
Test Statistic	206.000
Standard Error	51.514
Standardized Test Statistic	-2.067
Asymptotic Sig.(2-sided test)	.039

Mann–Whitney U test for the effects of age group and length of residency groups on housing feature variables

Age: There was a significant difference in the green cover percentage between residents aged 51 and below (group 1) and those aged 52 and above (group 2), with a cut-off at $p < .05$ (Tables 11 and 12).

The average green cover percentage for group (1) is 0.098, and the green cover percentage for group (2) is 0.298.

Table 11: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of green cover percent in radius of 20m (%) is the same across categories of mean 51.	Independent-Samples Mann-Whitney U Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 12: Independent-samples Mann–Whitney U test summary

Total N	50
Mann-Whitney U	488.000
Wilcoxon W	741.000
Test Statistic	488.000
Standard Error	49.981
Standardized Test Statistic	3.601
Asymptotic Sig.(2-sided test)	<.001

Length of residency on building density: There is a significant difference in the building density between length of residency of 8.6 years and below (group 1) and 8.7 years and above (group 2), with a cut-off at $p < .05$ (Tables 13 and 14).

The average building density for group (1) is 2.79, and that for group (2) is 2.32.

Table 13: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of building density (build-up area/land size) is the same across categories of mean 8.6 length residence.	Independent-Samples Mann-Whitney U Test	.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 14: Independent-samples Mann–Whitney U test summary

Total N	50
Mann-Whitney U	147.000
Wilcoxon W	472.000
Test Statistic	147.000
Standard Error	51.224
Standardized Test Statistic	-3.231
Asymptotic Sig.(2-sided test)	.001

Length of residency on unit natural ventilation: There was a significant difference in the unit natural ventilation between length of residency of 8.6 years and below (group 1) and 8.7 years and above (group 2), with a cut-off at $p < .05$ (Tables 15 and 16).

The average unit natural ventilation for group (1) is 1.27, and that for group (2) is 1.52.

Table 15: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of unit natural ventilation (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high) is the same across categories of mean 8.6 length residence.	Independent-Samples Mann-Whitney U Test	.019	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Units natural ventilation (1=very low, 1.25=low, 1.5=middle, 1.75=high, 2=very high) across the length of residency.

Table 16: Independent-samples Mann–Whitney U test summary

Total N	50
Mann-Whitney U	430.000
Wilcoxon W	755.000
Test Statistic	430.000
Standard Error	49.907
Standardized Test Statistic	2.354
Asymptotic Sig.(2-sided test)	.019

Length of residency on the percentage of green cover: There is a significant difference in the green cover percentage between those with a length of residency of 8.6 years and below (group 1) and those with a length of residency of 8.7 years and above (group 2), with a cut-off at $p < .05$ (Tables 17 and 18).

The average green cover percentage for group (1) is 0.078, and that for group (2) is 0.293.

Table 17: Hypothesis test summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The distribution of green cover percent in radius of 20m (%) is the same across categories of mean 8.6 length residence.	Independent-Samples Mann-Whitney U Test	<.001	Reject the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

Table 18: Independent-samples Mann–Whitney U test summary

Total N	50
Mann-Whitney U	513.000
Wilcoxon W	838.000
Test Statistic	513.000
Standard Error	50.344
Standardized Test Statistic	3.983
Asymptotic Sig.(2-sided test)	<.001

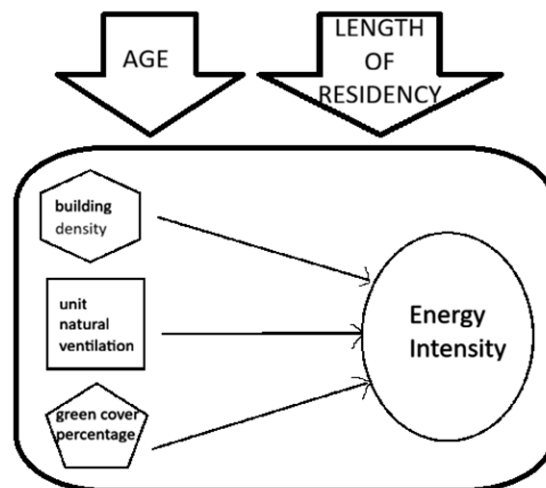
The above series of analyses revealed that there is a significant correlation between some of the physical characteristics/features of the housing and EI (Table 5). It is worth investigating further how these features contribute to EI and the role they play in the interaction between dwellers' socio-demographic factors and EI.

Furthermore, the results suggest that age and length of residency influence energy intensity through their selection of building density, unit natural ventilation, and green cover percentage. Specifically, a participant's length of residency may impact energy intensity via their building density, their unit natural ventilation, and green cover percentage. Our findings suggest that dwellers with longer length of residency tend to have lower energy intensity, which may be due to higher unit natural ventilation and green cover percentage, with lower building density. Age may also impact energy intensity; specifically, older dwellers tend to have lower energy intensity, which may be attributed to the higher green cover percentage in surrounding area of their dwelling units. In particular, 52-years old and above residents tend to stay in their residential unit longer (8.7 years on average, age and length of residency correlation $r(50) = .50$, $p < .001$) than younger residents (residents from 51 years old and below), and their energy intensity is also lower. This is likely occurred due to lower building density, higher unit natural ventilation and, more importantly, a higher percentage of green cover in the surrounding area of their dwelling units.

Finally, green cover percentage seems to be a significant factor influencing energy intensity for both age and length of residency. In fact, it is the only physical feature of housing that is significantly correlated with both age and length of residency. This underscores the importance of the natural environment for dwellers over time, i.e., as one aged and stayed in a residence for a long time, the natural environment surrounding one's residence appears to increase in importance. Studies on the impact of exposure to the natural environment on an individual's well-being may offer a plausible explanation. For example, a study by Nghiem et al. (2021) revealed that exposure to nature has a significant positive effect on emotional wellness and a restorative effect on the mind. Ramkissoon (2024) emphasizes the role of

nature in promoting residents' well-being and quality of life. Future research may examine more closely whether the influence of the natural environment on individual well-being increases with the age and length of residency of dwellers. This has implications for the planning and design of mass or public housing that considers dwellers' long-term well-being. In summary, the results of this study suggest that in Mashhad apartment housing, occupants' socio-demographic characteristics, i.e., age and length of residency, have the potential to determine the choice of physical features in relation to EI. Age and length of residency may moderate the associations between specific housing physical features and EI (refer to Figure 2). Specifically, the impacts of building density, unit natural ventilation and green cover percentage on EI vary across the different age and length of residency groups. Housing physical characteristics may also mediate the impact of age and length of residency on energy intensity. Further research is needed to determine their causal relationships and whether the abovementioned roles (moderator and mediator) are valid when a larger sample size and longitudinal data are used.

Fig. 2: Role of occupant age and length of residency in moderating the correlations between building density, unit natural ventilation, and greenery and EI



5. Discussion

The results show significant associations between some of the occupants' demographic characteristics (i.e., age and length of residence) and the dwelling unit EI. The results also show the correlations between housing physical features with both dwelling unit EI and occupants' demographic characteristics.

Age and length of residency have the potential to address occupants' motivations for housing physical features in relation to dwelling unit energy performance. The correlation between housing features and EI is more evident than the correlation between housing features and occupants' demographic characteristics. Although there are substantial correlations between building features and dwelling unit EI, the findings suggest that occupants pay more attention to features at the neighbourhood scale (greenery, density, ventilation) than at the building scale (façade features, dwelling unit features). This might be a sign of their lack of expertise, profession, information, awareness, and knowledge at the building scale (Asadpoor and Jusan, 2017, Sari, 2021), which may point to the necessity of improving occupants' awareness and knowledge through information provision (see Asadpoor and Jahanshahi 2025;

Rashed et al., 2023; Sari, 2021). The lack of significant correlation between occupants' demographic characteristics and housing features at the building scale, i.e., façades, buildings, and units, might be due to the lack of significant variation in the selected apartment housing features; therefore, effective differentiation in occupants' choice behaviours was limited.

Age is a sign of maturity, experience, know-how, stability, and self-learning, and length of residence is a sign of rootedness, belonging, stability, dependency, and attachment (e.g., Moser and Uzzell, 2003; Rapoport, 2000; da Luz Reis & Lay, 2010; EPA, 2021). Occupants' sense of control provided by their maturity, experience, self-learning, proper economic status, stability, belongingness, dependency, and attachment could improve their pro-environmental behaviours (e.g., Ajzein, 2011; Ramkissoo et al., 2014, 2020a, 2020b) and assist them in paying proper attention to their selection of housing features in accordance with bioclimatic principles, which have positive impacts on the energy performance of their housing units.

The findings of the present study contradict those of previous studies in the USA and Australia, whereby occupants' education, awareness, and availability of comprehensive information were recognized as indicators of their positive attitudes toward housing EE (Antonopoulos, et al., 2019; Gower, 2021; Rashed et al., 2023). Antonopoulos et al. (2019) stressed that affluent people, regardless of their age, do not pay proper attention to housing EE and that they may consume more energy without considering EE necessities. People's education could have positive impacts on the affluent people's attention to housing energy consumption (Antonopoulos, et al., 2019). This might be a sign of the significant role of cultural origins in traditional societies such as Iran, which have deep socio-cultural boundaries and ritual ties. This is in fact a complicated and multi-aspect subject that needs further investigations in future studies. The comparison between the findings of the current study and those of previous works also stresses the differences between occupants' housing motivations in different societies and the importance of socio-cultural aspects (Rapoport, 2000). Although energy efficiency is a global challenge, developing proper action plans depends on the identification of the interplay between the different aspects of the subject at the local scale while considering people's socio-demographic characteristics.

Our findings indicate that the implementation of housing sustainability features is more fruitful when they are relevant to occupants' socio-demographic characteristics. In the case of the apartment housing of Mashhad, this also means that facilitating the provision of a sense of control is a necessary platform for paying proper attention to the selection of proper housing sustainability features.

Given the above discussion, some of the potential implications of this study for mass housing in a broader context could be mentioned as follows:

- 1- Given the results of the present study (Tables 4, 5, and 6), the occupants' age and length of residency are significantly correlated with EI and the physical features of the housing. Although many housing features are correlated with EI, age and length of residency are only correlated with building density, unit natural ventilation, and the percentage of green cover in the surrounding area. Additionally, among all the socio-demographic characteristics, only age and length of residency are correlated with EI. This means that the occupants would require quite a long time to gradually pay proper

attention to higher levels of housing needs and other realms of housing operations, e.g., energy performance without a detailed understanding. These findings are signs of a lack of proper information and awareness in the majority of occupants of apartment housing in Mashhad, Iran, as also stated by some previous studies (Asadpoor and Jusan, 2017; Rashed, et al., 2023; Sari, 2021). These studies emphasized that occupants are mostly people with low levels of expertise, profession, and knowledge, which make them unable to properly consider the impacts of the physical features of housing on EI. This reflects the significant information, awareness, and knowledge gaps in the housing market, which should be bridged in future housing studies.

- 2- This study is especially beneficial for developing a user-centric energy efficiency assessment platform for mass apartment housing in many countries across the globe. The developed analytical model makes it possible to identify the interplay between occupants' socio-demographic characteristics, housing features, and neighbourhood characteristics in terms of their impact on the energy performance of mass apartment housing, whereby the majority of end-users are absent during the design and delivery process.
- 3- Following previous studies (e.g., Antonopoulos, et al., 2019; Asadpoor, et al., 2021; Asadpoor and Jahanshahi, 2025; Biglari, et al., 2026; Gower, 2021; Rashed, et al., 2023), this study also addressed the multi-dimensional roles of occupants' socio-demographic characteristics in impacting housing energy efficiency. These studies have indicated the importance of considering occupants' characteristics in any housing energy efficiency assessment tool and AI-based recommendation platform. This would contribute to more concrete and accountable outputs.
- 4- The AI-based platform is especially necessary for mass housing because it provides the opportunity to link occupants' socio-demographic characteristics to housing features in relation to energy efficiency in the absence of end-users. This makes it also possible to practically consider the interrelationships between the features and occupants' real daily life needs in future mass housing development.
- 5- Such a platform also has the potential to bridge occupants' information and awareness gap, and hence to assist them in finding a more suitable energy efficient dwelling unit on the basis of their specific needs and desires. This is necessary for mass housing EE, whereby housing clients with different energy needs confront a wide range of housing products with a variety of physical features located under various environmental conditions.
- 6- This platform would also benefit the different stakeholders of the mass housing industry, e.g., the government, city councils, planners, designers, and developers, by bridging their knowledge gap, affording them a specific understanding of their clients' motivations, and assisting in implementing the house seekers' needs, demands, and desires in their future plans.
- 7- Furthermore, this study contributes significantly to improving energy justice and equity by helping different groups of vulnerable people with different socio-demographic characteristics and housing needs to achieve a more congruent energy-efficient dwelling unit on the basis of their affordability, demands, and expectations.

Future studies would require larger sample sizes, measurements across different time frames, and sophisticated analyses to more accurately and precisely identify the interplay between occupants' demographic characteristics, housing features, and energy efficiency.

6. Conclusion

Housing energy efficiency depends on a balanced interplay among various aspects related to housing architecture, e.g., human, building, environment, and climate. Given the main objective of the study, the results of the analysis conducted on the developed database revealed a) strong correlations between housing features and unit EI and b) the effect of occupants' characteristics in moderating the relationship between housing features and unit EI. The findings of the present study emphasize the impacts of occupants' demographic characteristics on the physical features and energy performance of a dwelling unit. The sense of control is identified as a critical factor in the selection of energy-related housing features and in improving the energy performance of dwelling units, which might be achieved in different ways in different societies and should be considered in the design/retrofitting of new/existing dwelling units to assist occupants in achieving a more suitable dwelling unit with proper energy performance.

The findings also indicate the necessity of providing information through education, training, and a smart informational platform, which is highly beneficial for low-experienced younger house seekers. This information provision has significant implications for HEE and energy justice and equity. The information provision has the potential to bridge a critical gap in mass apartment housing, whereby the occupants are mostly absent during the housing provision procedure. We recognize the limitations of this study in terms of sample size and the non-normal distribution of the collected data. Future studies could consider a larger sample size, measurement across different time frames, and more sophisticated analysis to reveal the intricacies of the interplay between occupants' demographic characteristics, housing features, and energy efficiency.

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Data availability

The datasets collected and/or analysed during this research are available from the corresponding author on reasonable request

Declarations

Ethical approval

The study was approved by the Research Ethics Committee of Islamic Azad University-Mashhad Branch, Iran. It is further certified that the study was conducted in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki, and its later amendments or comparable ethical standards.

Consent to Participate

Informed Consent was obtained from all individual participants included in the study.

Consent to Publish

Not applicable

Competing interests

The authors declare no competing interests.

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