Energy & Buildings 361 (2026) 117498

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enb

Key influencing factors of generation Z's residential energy behaviour: Insights from a gamified investigation for the energy transition

Yehui Peng *, Lia Marchi, Jacopo Gaspari

Department of Architecture, University of Bologna, Via Risorgimento 2, Bologna 40136, Italy

ARTICLE INFO

Keywords:
Generation Z
Energy-saving
Energy use
Behaviour change
Gamification
Residential

ABSTRACT

Residential energy behaviour has become a vital branch within building energy efficiency research. Most existing studies focus on quantitative methods to examine energy-saving simulations and potential from a technological perspective. However, understanding the factors shaping users' residential energy behaviour and their decisions to adopt/ not adopt technologies is crucial. Otherwise, cutting-edge technologies are failing to deliver their full potential as scientists had anticipated. As a key generation for future energy consumption and transition, Generation Z remains underexplored regarding its potential role in the intersection of global climate action or in accelerating behavioural change. This article investigates the characteristics and key influencing factors shaping Generation Z's residential energy behaviour and engagement in building retrofits. An innovative gamification-based investigation method distinguishes this study from previous research employing traditional quantitative questionnaires. This method helps to adapt to the characteristics and needs of Generation Z, improving survey participation and quality. The study adopts an interdisciplinary approach to analyse key factors influencing Generation Z's residential energy behaviour across four dimensions: sociodemographic, individual, psychological and situation factors. Research obtained a total of 282 valid responses. Based on the findings, four behavioural potential levers tailored to Gen Z are proposed: (1) enhancing the visibility and readability of energy information; (2) providing tiered behaviour guidance strategies; (3) conducting scenario-based energy-saving education and activities; and (4) developing user-centred digital tools and incentive mechanisms. This research offers insights for future energy-saving strategies and technology deployment targeting younger users, responding to global climate action strategies for youth engagement.

1. Introduction

1.1. Background and position

Climate change has increased the frequency and severity of extreme weather events, making energy transition an urgent global priority. The Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report highlights that promoting energy system transformation requires technological innovation, policy initiatives, effective management of energy service demand, and active public engagement [1]. In fact, technological advances do not automatically lead to energy savings. Studies show that although green buildings have over 50% savings potential, actual efficiency gains are often constrained by occupants' behaviour [2]. Therefore, the transition's success depends heavily on users' understanding, acceptance, and willingness to adopt sustainable practices, particularly in the residential sector.

The EU has recently elevated "energy efficiency first" as a legal principle (Directive EU/2023/1791) [3]. In the building sectors, improving energy efficiency means achieving the same performance with less energy input [4]. While many scholars are contributing to retrofitting technologies and digital renovation tools, renovation rates in the EU are below 1% annually [5]. Besides, technological advances have not slowed the rise in energy demand [6]. Research indicated that behavioural change alone could reduce demand by 10–15% [7]. Behavioural change offers the most immediate and cost-effective strategy for reducing consumption. Together, closing the gap between technical potential and practice should involve engagement with occupant behaviour, rather than relying solely on technological advances.

Occupant behaviour encompasses daily interactions with building systems, from operating windows and thermostats to using appliances and directly consuming energy sources [8,9]. To date, many studies have explored the use of models to predict consumption. However, due

* Corresponding author.
E-mail address: yehui.peng2@unibo.it (Y. Peng).

https://doi.org/10.1016/j.enbuild.2026.117498
Received 21 November 2025; Received in revised form 7 March 2026; Accepted 16 April 2026
Available online 17 April 2026
0378-7788/

to the high complexity of occupant behaviour leading to the widespread existence of the "energy performance gap" [10], particularly pronounced deviations between the predicted and operational phases [11,12].

Although behavioural change is a key asset in non-technical pathways, its underlying drivers, barriers, and transformation mechanisms still require systematic understanding and interdisciplinary integration [13]. Levesque et al. [14] found that combining energy-saving behaviour with low-energy technologies could reduce global building energy use by nearly half by 2050. On the other hand, numerous studies in social psychology have attempted to uncover the motivations and willingness behind users' energy-saving behaviour, intending to design more targeted intervention measures [15–17].

Sociodemographic differences further complicate this picture. As Bardazzi and Pazienza's [22] research shows, differences in intergenerational behavioural attitudes are a reasonable outcome of changing historical and social backgrounds. Older generations such as Baby Boomers (born between 1946 and 1964) [18], and Generation X (born between 1965 and 1976) [19], tend to maintain fixed lifestyles and energy routines, with limited scope for behavioural adjustment; in some cases, retirement even increases energy use [20–22]. Millennials (born between 1981 and 1996) [23] have mostly started new families and may be limited by family size/child-rearing. In contrast, Generation Alpha (born after 2010) [24] is largely still in childhood or adolescence and hasn't established credit. They lack direct decision-making authority over household energy use, and waiting until they reach adulthood would mean missing the narrow window for climate action.

Given this context, Generation Z (born in the mid-1990 s to early 2010 s) [25–27] is therefore positioned at the forefront of the energy transition. Generation Z (Gen Z) grew up in an environment where information and communication technologies (ICT) are deeply embedded [26]. A survey reported that more than 69% of Gen Z respondents expressed anxiety about the future climate issues and dissatisfaction with slow policy responses when encountering climate-related topics on social media [28], while also showing broadly positive attitudes toward energy efficiency and carbon reduction [29]. However, a substantial gap persists between self-reported literacy and actual technical understanding [30], which may be attributed to a lack of systematic education on energy topics [31].

Mitigating climate change requires a multi-decade effort. The IPCC noted that near-term actions to accelerate adaptation will reduce the threat posed by future climate change [32]. If Gen Z fails to accelerate behavioural change and widespread adoption of sustainable practices, there may not be enough time for subsequent generations to reverse course. Unless disruptive innovations rapidly transform the global energy system (a scenario that remains uncertain). Otherwise, Gen Z may be the last generation able to act within the narrow timeframe necessary to mitigate climate change.

Current research leaves the following gaps: First, although many studies have contributed to sociodemographic influences on energy behaviour, the drivers of Gen Z's residential energy use remain poorly understood, leaving uncertainty about how this generation will influence the energy transition. Second, current research rarely links individual factors to external factors such as building energy-saving facilities and technologies, making it unclear whether the younger generation of users has the capability or willingness to implement energy-saving measures or renovations. Third, most studies focus on willingness and attitudes but seldom identify specific behavioural levers that can provide actionable guidance and long-term benefits for young users. Finally, widely used survey (questionnaire) methods are prone to recall bias, social desirability [33], and low engagement among younger groups [34], thereby limiting the authenticity and reliability of behavioural data. To address these gaps, the scope of this article is to examine Gen Z's residential energy-use patterns and the factors influencing their adoption or non-adoption of energy-saving behaviours, as well as their understanding of and preferences for building technologies and retrofitting measures. Accordingly, this study's findings offer a set of key levers to accelerate Gen Z's contribution to the energy transition.

1.2. Cross-cutting framework for understanding Gen Z

This article draws on experience from previous research and adopts an interdisciplinary perspective to structure the analytical framework for understanding residential energy-saving behaviours among Gen Z. Most studies explain household energy-saving behaviour through two complementary frameworks: one focuses on behaviour-change pathways, clarifying how behavioural change occurs. As Steg [35] observed, individuals must progress through three stages to achieve energy-saving change: first, recognising the necessity of reducing energy use and the feasible approaches to achieve it; second, developing the motivation to save energy; and finally, translating this into concrete actions. Complementing this, the other framework examines the sources of influencing factors to understand the underlying reasons for household energy-saving behaviour. Zhang et al. [36] categorise these sources from a multi-level perspective, including the individual level (objective socio-demographic characteristics and subjective attributes), the external level (market/society/government-related factors), and energy-saving intention (the degree of readiness to implement energy-saving behaviours).

Together, these two frameworks form a coherent explanatory chain. The former provides a clear cognition–motivation–action pathway, while the latter offers further clarification by identifying which factors facilitate/obstacles for energy saving, which factors shape the awareness at the motivational stage, and which factors determine whether motivation can be translated into actual behaviour and adoption at the action stage.

To integrate these perspectives, this study develops a four-dimensional conceptual framework, which is Who–What–Why–Act. The framework first considers sociodemographic and residential building information (Who), then explores individual knowledge and awareness (What), and finally examines psychological drivers (Why) and how situational factors facilitate the translation of intention into actual energy-saving behaviour (Act). Specifically, the dimensions include sub-factors as follows:

(a) Sociodemographic factors: age, gender, educational level, living patterns, building information (such as building type, construction period, energy systems), and responsibility for energy bills.
(b) Individual factors: energy-knowledge, habits, lifestyle, and comfort preferences.
(c) Psychological factors: attitudes, subjective norms (SN), perceived behavioural control (PBC), and personal moral norms (PMN).
(d) Situational factors: social norms, physical infrastructure, costs, incentives, and technical facilities.

The above factors are among the most frequently discussed in the previous literature [37–40], to explain differences in household energy use and provide the structural foundation for the subsequent gamified investigation design (Fig. 1). Other factors that fall beyond the measurable or defined scope of this study were not considered.

Sociodemographic variables are widely recognised as key moderators for energy-related behaviours. This dimension includes age, gender, education level, income, household size, house ownership, and building information (e.g., building type, construction period, and energy systems) [15,41–44]. Several studies reported age- and gender-based differences, such as elderly users exhibiting lower flexibility in changing behavioural patterns [45,46]. Age makes a difference that persists even among younger populations [47]. In contrast, females are generally more inclined toward sustainable values and energy-conscious attitudes [42]. Furthermore, differences in educational level can lead to more than a twofold variation in energy-saving indices [48]. Higher levels of education are associated with stronger environmental awareness and

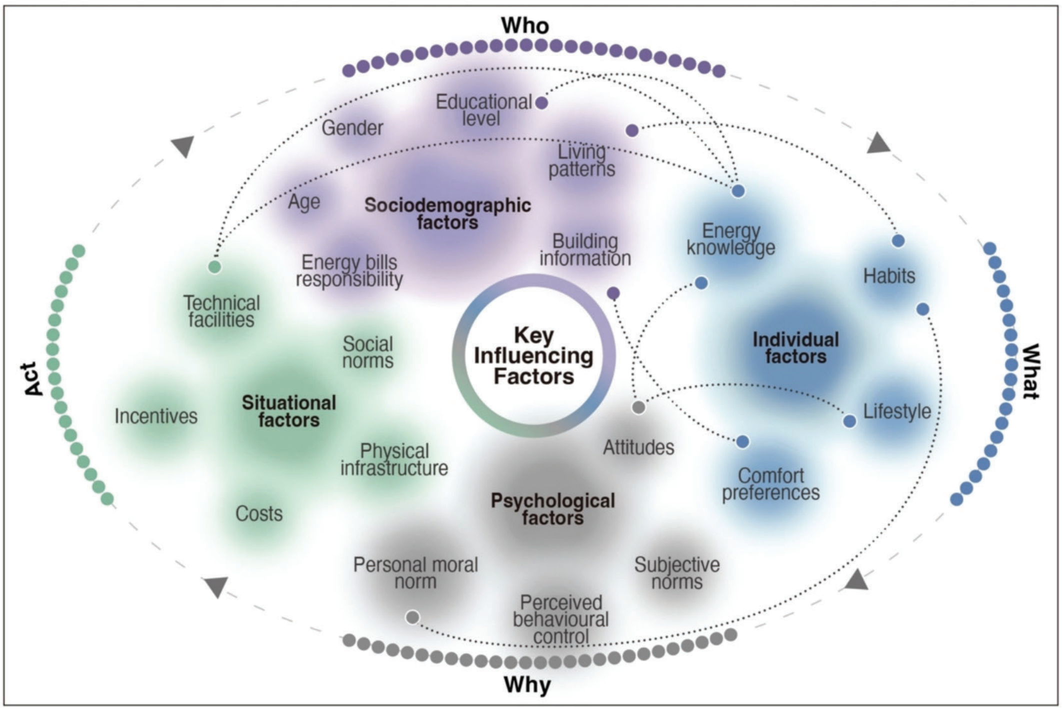

Fig. 1. Conceptual framework of key factors influencing Gen Z's residential energy behaviour.

greater knowledge transfer within households [49]. Building ownership also brings some impacts. Poruschi and Ambrey [50] indicated that tenants and households living in non-detached dwellings face significant barriers to adopting energy-saving actions.

Individual factors refer to residents' accumulated knowledge, experience, values, and behavioural habits, which exhibit greater temporal stability than other variables [47]. This dimension includes energy knowledge, saving capacity, daily lifestyle, comfort preferences, and environmental responsibility [40,51]. Energy knowledge and education are widely regarded as the starting point of energy-saving behaviour [52]. While some studies report a positive correlation between knowledge levels and energy-saving practices [53], others report mixed evidence, showing that knowledge accumulation does not necessarily translate into more proactive attitudes or actions [54,55]. Among younger generations, the link between knowledge and behaviour appears weak [55]. This "knowledge–action gap" is particularly evident, as cognition does not guarantee behavioural change. In addition, personal habits and lifestyle play a crucial role. Elsharkawy et al. [56] found that even when building energy performance was significantly improved through retrofits, the potential savings were offset by poor behavioural rebound effects. Similarly, lifestyle variables substantially shape household electricity consumption [57].

Psychological drivers are central to explaining individual energy-saving behaviour. Within environmental psychology, the Theory of Planned Behaviour (TPB) provides a robust framework for predicting and interpreting energy-related actions. Studies show that positive attitudes and strong SN can enhance energy-saving intentions and behaviours [58,59], while PBC serves as a critical pathway through which intentions translate into actual practices [60]. In other words, when users believe they can save energy, their likelihood of active engagement increases significantly [61]. Building on this framework, Boomsma et al. [62] found that among social housing tenants in Southwest England, positive attitudes and strong SN are closely associated with heating and other energy-saving behaviours. Extending the TPB model, Tan [63] demonstrated that PMN significantly promote the adoption of energy-efficient appliances. Similarly, Du and Pan [47] verified this finding in a university dormitory context; incorporating PMN into the TPB framework improved the model's explanatory power by 21%. Motivation alone is therefore insufficient to explain energy practices. Even with positive attitudes, actual consumption may remain constrained by entrenched habits [64]. According to Lindenberg and Steg [65], when energy-saving behaviours require high costs, users often lack motivation, whereas low-cost actions are more readily adopted.

Situational factors refer to external enablers and constraints affecting energy-saving behaviour [40], including social norms, physical infrastructure, informational and promotional activities, incentives, policies and regulations, costs, technical facilities, and geographical or climatic factors [37–39,66–68]. These external conditions largely determine whether energy-saving actions can occur. Cross-national surveys in Europe show that persistently high energy bills weakened young tenants' energy-saving motivation and increased the risk of energy poverty [69]. Poortinga et al. [76] noted that technological measures are generally more accepted than behavioural interventions, and that schemes with lower costs or clear financial incentives are more likely to be adopted [70]. However, high upfront investment costs [71] and restrictions on building conditions, landlord decisions, user rights, and contractual obligations [72] remain significant barriers for young tenants seeking to implement energy retrofits.

Beyond economic and technical conditions, social influences are also highly significant. Yue et al. [39] found that energy-saving behaviour is powerfully shaped by social norms, promotional campaigns, and reward–punishment mechanisms, with informational and promotional activities exerting the strongest motivational effects. Notably, the cognitive differences among younger generations regarding their investment preferences and willingness to adopt energy-saving measures remain underexplored [73], highlighting a gap in understanding the interplay between external contexts and behavioural decision-making.

In summary, existing studies have offered valuable insights into residential energy behaviour. However, significant gaps remain in understanding Gen Z as an emerging energy consumer group. Most research relies on single-disciplinary perspectives (mainly psychological frameworks) to explain intentions, while few studies adopt an integrated approach that considers the combined influence of sociodemographic, individual, psychological, and situational factors [35]. As energy technologies evolve and Gen Z becomes a key decision-maker in residential energy use, the lack of integrated research may limit the capacity to understand and guide their behavioural transitions.

Measurement items related to these factors were adapted from established surveys and prior empirical studies to ensure construct validity and cross-study comparability.

2. Methodology

The methodology is grounded in the multidimensional framework developed above, which captures the multiple factors shaping Gen Z's residential energy-related decision-making. First, it critically analyses the applicability of existing survey methods among Gen Z, highlighting their limitations in mobilisation and participation, thus prompting a new tool to involve Gen Z. Within this methodological framework, this study focuses on the following three research questions:

- **RQ1:** Which key factors play a role in influencing Gen Z's residential energy-saving decision-making?
- **RQ2:** What is the level of awareness and knowledge among Gen Z regarding building energy-saving measures and retrofits?
- **RQ 3:** To what extent are Gen Z participants willing to adopt these measures, and what factors promote/ hinder this willingness?

2.1. Reflecting on approaches for understanding Gen Z's energy use

Conventional methods such as questionnaires, focus groups, and interviews are widely used in building energy behaviour research [52,74–77]. However, as experienced by Vathy et al. [78], traditional survey methods have a low response rate among the younger participants. This faces limitations when behaviours are context-dependent and complex. Participants may misrepresent their actions, fail to recall actual circumstances [79], or adapt to perceived researcher expectations, called the Hawthorne effect [34]. Younger respondents often adopt satisficing strategies, such as "speeding" (completing the questionnaire in an unrealistically short time) or "straight lining" (providing non-differentiated responses), which compromises data quality [80]. Based on this, it is necessary to develop a tool adapted for this generation. In contrast, incorporating gamification elements enhances participation, motivation, and engagement [81]. Wang et al. [49] reported that gamification can effectively foster sustained engagement in sustainable practices when supported by policy, adapted to context, and refined through iteration.

Although there is no single definition of gamified investigations, they share similarities with serious games, which Marsh defines as interactive forms that use narratives, game mechanics, or simulations to convey information and influence behaviour [82].

This study places residential energy use decision-making within an immersive scene, enabling participants to demonstrate their behavioural tendencies in a way that traditional surveys cannot capture. The tool was named ENERGON. The ENERGON is comparable to a standard questionnaire in terms of survey objectives and question design logic. Its innovation lies in the introduction of gamified elements at the participants' front end, such as narrative scenarios, score systems and feedback mechanisms. These features were intended to reduce the risk of low-quality responses (as discussed above), thereby enhancing engagement among Gen Z respondents and improving data quality. At the same time, Gen Z is more accustomed to interactive digital experiences, and this format aligns more closely with their response habits and participation preferences.

Besides, the study adopts a gamified investigation design rather than a game-theoretical framework. Although individual decision-making processes might be influenced by multiple interacting factors, these are considered only as background context in the back-end interpretation of results. Thus, ENERGON is not a general tool but a purpose-built, innovative methodological approach that aligns generational characteristics with research needs to generate reliable, context-rich behavioural data.

Specifically, the tool is used to investigate the following three objectives.

(a) To analyse the key factors influencing Gen Z's decision-making of residential energy use.
(b) Assess Gen Z's understanding and willingness to adopt/not adopt energy-saving measures or retrofits.
(c) To identify potential levers that can stimulate long-term behavioural change and discuss intervention strategies to accelerate such change.

The methodological framework of this study is illustrated in Fig. 2. The process consists of four phases: 1) Prototype development: Designing the content and structure of ENERGON and conducting small-scale validation to ensure methodological robustness. 2) Data collection: Deploying the validated game widely to gather baseline data from Gen Z participants. 3) Data analysis: Applying mixed qualitative and quantitative methods to identify the key factors shaping Gen Z's residential energy-saving decision-making. 4) Discussion and output: Discussing potential behavioural levers and generating recommendations to accelerate sustainable residential energy practices.

2.2. Prototype development

2.2.1. Select key factors

To identify the key factors associated with this process, Table 1 reviews the relevant empirical contributions on residential energy behaviour from the past decade (2015–2025), mapping the main influencing variables that have been widely explored in the literature. As shown in Table 1, sociodemographic (1) and psychological (3) factors are the most frequently examined factors, but also individual (2) and situational (4) factors have been proven to exert a significant influence on energy behaviour.

2.2.2. Preliminary structure and platform

Four key dimensions influencing Generation Z's residential energy use were identified above, and the factors contained therein were translated into scenario questions.

The ENERGON investigation game was implemented on the Typeform platform (web version), a professional tool for creating interactive questionnaires. Typeform provides cross-device accessibility, adaptive language settings, and conditional logic, which met the study's requirements for usability, branching design, and reliable data tracking.

All visual materials were generated with the assistance of AI tools (Doubao, CreationAgent v1.0 Beta, 2025 version) and subsequently refined in Adobe Photoshop (2023 version). The purpose is to avoid potential confidentiality or copyright issues arising from the use of authentic images and to ensure the visuals accurately represent the intended meaning and context. Participants were informed in advance about the tools and purpose of these images.

Access to ENERGON via an invitation link or QR code, with the system automatically adapting to mobile or desktop interfaces and switching to the relevant language version according to device settings. This design reduced potential language barriers and broadened sample coverage. During gameplay, all responses were automatically stored in the platform backend and exported as raw datasets for statistical analysis.

2.2.3. Focus group

After developing the initial ENERGON prototype, the research team organised a focus group on 13th March to refine its content and structure. The focus group aimed to evaluate the clarity and relevance of the preliminary design for the target user pool.

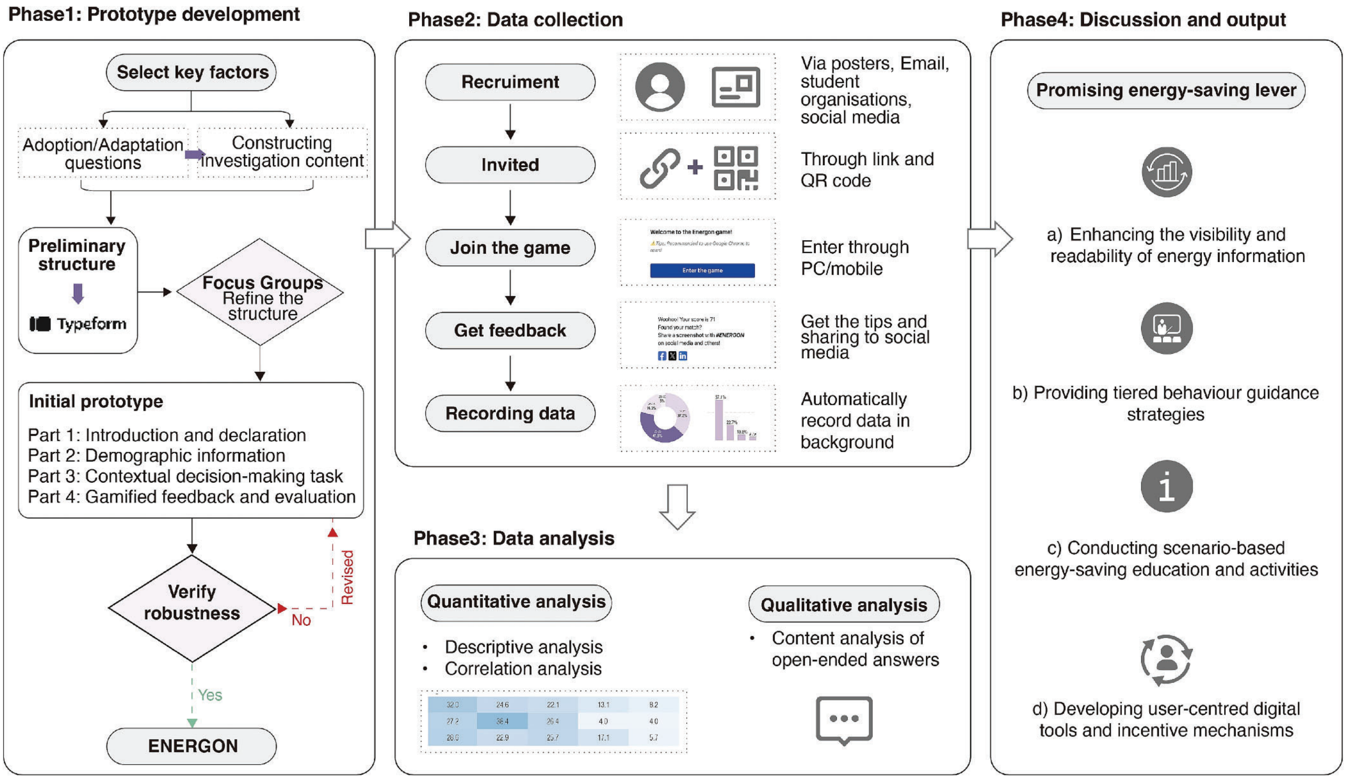

Fig. 2. Workflow framework for research.

Table 1
Key influencing variables in residential energy behaviour studies (2015–2025).

Source	①	②	③	④
Jareemit and Limmeechokchai, 2019 [83]	•	•	•	•
Zhang et al., 2020 [84]	•	•	•	•
Paço and Lavrador, 2017 [55]	•	•	•	–
Hou and Law, 2024 [60]	•	•	•	–
Pothitou et al., 2016 [85]	•	•	•	•
Stancu et al., 2025 [86]	•	•	•	–
Hou, 2024 [70]	•	•	–	•
Trotta, 2018 [87]	•	•	•	•
Chen and Guo, 2022 [88]	•	•	•	–
Alomari et al., 2022 [89]	–	•	•	–
Liu et al., 2021 [17]	•	•	•	•
Bélaïd and Joumni, 2020 [90]	•	•	•	•
Niamir et al., 2020 [91]	•	•	•	•
Bae et al., 2024 [92]	•	•	•	•
Vogiatzi et al., 2018 [49]	•	•	•	•
Ru et al., 2018 [93]	•	–	•	•
Liu et al., 2020 [15]	•	–	•	–

Note: ① Sociodemographic factors;② Individual factors; ③ Psychological factors; ④ Situational factors.

The focus group included ten doctoral and six master's students from The University of Bologna (UNIBO), Cesena Campus, all matching the target demographic. The discussion was facilitated by the research team and documented. Feedback was concentrated on the following aspects:

- Scenario design: Certain narratives were considered insufficiently aligned with daily residential contexts and should distinguish between independent living, shared housing, and living with family members, reflecting common UNIBO arrangements.
- Interaction flow: Some parts were too time-consuming, potentially affecting user experience.
- Gamification mechanism: The points-and-feedback system was well received, though participants recommended adding a social-sharing feature.
- Language clarity: Some items were overly long, reducing readability and comprehension.

Based on this feedback, the research team iteratively revised the content and structure of ENERGON, producing an improved version.

2.2.4. *Initial prototype*

The initial prototype comprised four sequential parts:

- Part 1: Introduction and declaration. Participants were provided with information about the research background, the gameplay process, and data anonymity. A statement was also included regarding the use of Artificial Intelligence tools in supporting the investigation.
- Part 2: Demographic information. Eleven questions captured socio-demographic characteristics and living conditions.
- Part 3: Contextual decision-making task. Daily scenarios were presented in a narrative format to immerse participants in contextualised decision-making. Within these storylines, 24 items relating to the four identified dimensions were embedded. To enhance contextual realism and relevance, branching narratives were introduced according to housing type. For example, participants living with their parents followed a slightly adapted storyline during the initial rounds before re-joining the main path.
- Part 4: Gamified feedback and evaluation. Participants provided reflections on the gameplay experience (e.g., willingness to participate again) and underwent a basic consistency check.

Gamification elements were embedded from the outset to increase engagement without turning the investigation into a test. Each response accrued invisible points during play and was revealed only after game completion. Based on the total score, participants were categorised into six representative user profiles. This gamified feedback aimed to help participants find their position in energy habits and encourage wider dissemination of the game among young communities through simple, visual labels. The feedback page consisted of two modules: a) Energy-saving tips, personalised, actionable recommendations tailored to each behavioural style. b) Energy partner matching, pairing participants on a complementary basis to stimulate collaboration and mutual support, thereby simulating community-level diffusion of behavioural change (Fig. 3).

2.2.5. Verify robustness

The ENERGON prototype (English version) was piloted during an international workshop attended by master's students in architecture at UNIBO on 3rd April. This step was verified for methodological robustness in a small and trusted group before large-scale deployment. The primary objectives of the pilot were to assess whether the game's structure and content were clearly understood, to evaluate the readability of the language, and to ensure the overall coherence and smoothness of gameplay.

Participants generally found the content clear and the flow consistent. Only a few participants suggested refinements related to visual design and feedback mechanisms. The formal version of the ENERGON question structure has been determined (Fig. 4).

2.3. Official launch and data collection

The UNIBO is a comprehensive research-oriented institution offering programmes from undergraduate to doctoral levels. The student population is predominantly aged 18 to 30, closely aligning with the target demographic of Gen Z, and students make up a considerable proportion of the city's population. This made the university a representative sampling source for the study.

To maximise sample coverage and enhance participation, the research team implemented a multi-channel recruitment strategy. This included circulating information through student representatives via email, engaging student organisations, posting invitations on social media, and displaying recruitment posters across the campus. Participation was entirely voluntary, with no financial incentives offered.

According to the latest official statistics, the UNIBO had an enrolment of more than 96,000 students according to the last available data which can be reduced to approximately 70,000 if only the Bologna Campus is considered while the rest are spread in the other Romagna Campuses [94]. Following sample size estimation approaches commonly used in related research, the calculation was based on the following formula [95]:

$$n = \frac{z^2 \cdot p(1-p)/e^2}{1 + \left(z^2 \cdot \frac{p(1-p)}{e^2 \cdot N}\right)}$$

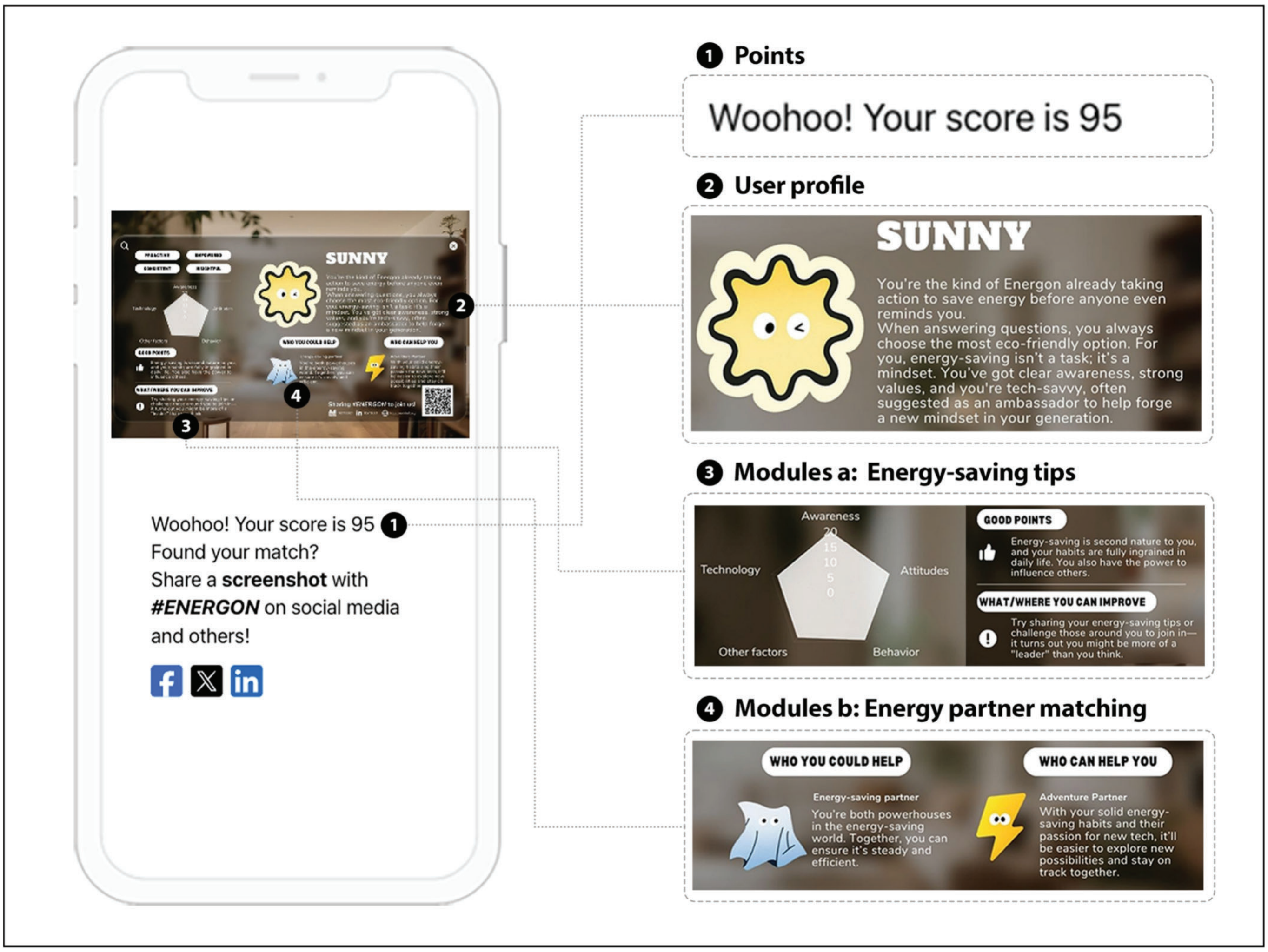

Fig. 3. Examples of gamification elements in the ENERGON.

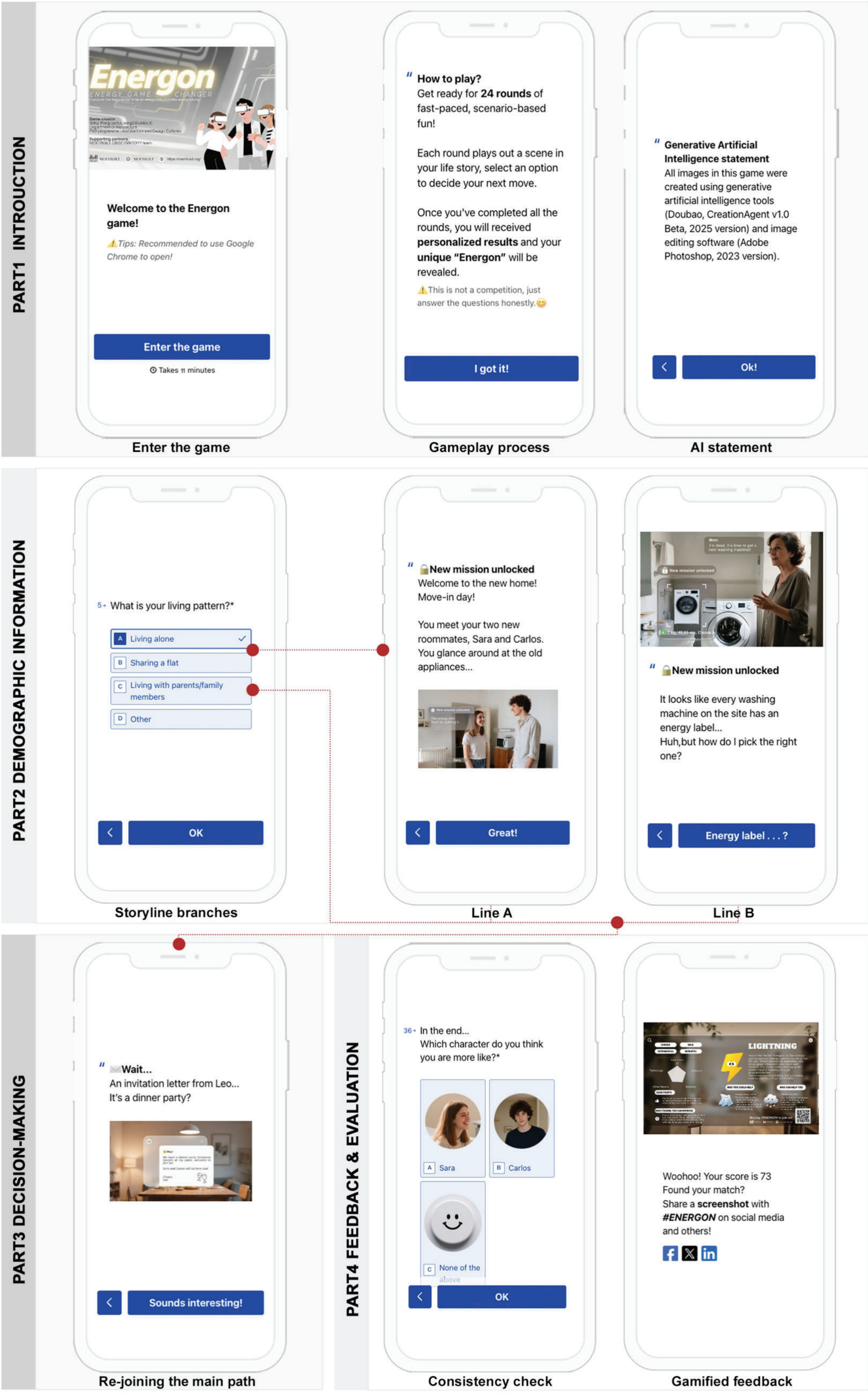

Fig. 4. ENERGON gamified investigation prototype interface.

In this research, N is total student population of the UNIBO, e is the margin of error, set at 0.05, and z is the z-score (1.65 for a 90% confidence level). Assuming the maximum value of $p(1-p)$ as 0.25. The resulting minimum required sample size is approximately 272 participants.

The ENERGON game was launched online from mid-June to mid-October, open to all enrolled students at the University of Bologna. The game took approximately 10 min to complete. A total of 331 questionnaires were collected, and after excluding ineligible responses, the final dataset comprised 282 valid responses.

2.4. Data analysis

This study adopted a mixed-method approach, integrating quantitative and qualitative analyses to systematically interpret Gen Z's behavioural choices in residential energy use scenarios and the underlying drivers of these choices.

Quantitative analysis began with descriptive statistics to summarise the sociodemographic factors. Subsequently, to determine the key correlation between variables, cross-tabulations are used for correlation analysis. The method follows the analytical logic of the cross-dimension framework and studies the interrelationships among multiple dimensions (sociodemographic, individual, psychological, and situational factors). Compare the frequency distributions of variable combinations to assess potential correlation trends and ensure the robustness and validity of the results. Qualitative analysis primarily involved content analysis of respondents' open-ended answers to capture insights beyond the predefined categories.

3. Results

3.1. Sociodemographic factors (Who)

In the first section of the game, there are 11 background questions to gather participants' demographic and residential information. The demographic background of the respondents is shown in Fig. 5. Most respondents, as shown in Fig. 5a, were aged 18–21 (37.2%) and 22–25 (41.5%), followed by 26–28 (16.3%), with the remaining 5% aged 29–30. Female participants accounted for 64.5%, males 34%, and 1.5% were nonbinary (Fig. 5b). Indicating a higher participation rate among females. The dataset considered in this study comprised exclusively participants from the University of Bologna (100%), with undergraduates representing 43.3%, postgraduates 44.3%, and doctoral students 12.4% (Fig. 5c). Shared accommodation (44.3%) and living with family members (40.8%) were the most common. Only 14.9% reported living alone (Fig. 5d).

Additionally, the building information illustrated in Fig. 6 shows that 57.1% of students reported living in low-rise apartments (1–5 floors), 22.7% in detached houses, 10.6% in semi-detached houses, and 6% in the student dormitory. A further 3.6% selected 'other', with high-rise buildings (five or more floors) being the most common response (Fig. 6a).

Regarding the construction period in Fig. 6b, 29.8% were unsure of the construction year. Among those who knew, 12.4% lived in pre-1980 buildings, 16.7% in retrofitted pre-1980. A further 17.4% resided in dwellings built between 1980 and 2000, while 6.7% lived in properties from that period that had undergone retrofitting. Dwellings built after 2000 accounted for 17% of the sample.

Fig. 6c shows heating systems were mainly independent (46.5%) or centralised (37.2%), while 16.3% were uncertain. Most students reported having temperature regulation or heat metering devices, with the most common being a temperature regulator (44%), a heat metering device (14.9%), or both (19.1%). An additional 10.6% reported having neither, and 11.4% were unsure (Fig. 6d).

The investigation on renewable energy allowed participants to select multiple options (Fig. 6e). 62.9% reported that their residence lacked any renewable energy systems, while 18.5% were unsure. Among those with such systems, 11.9% reported having photovoltaic panels, 5% solar thermal collectors, and 1.7% geothermal systems. For energy bills illustrate in Fig. 6f, 40.8% were paid by parents or family, 34.8% shared with roommates, and 23.4% included in rent, while 1.1% were unsure.

3.2. Individual factors (What)

The second dimension examines the individual characteristics of Gen Z respondents (Fig. 7), including energy-related knowledge, behavioural habits, lifestyle, and comfort preferences. Regarding energy-efficiency awareness, 41.9% reported always or usually checking appliance energy labels, 42.2% did so only sometimes or rarely, and 14.9% never did. Among respondents living alone and in shared accommodation (n = 167), 30.4% carefully reviewed energy bills, while 54.4% only skimmed them or focused on total cost. Only 8% expressed no concern. Open-ended responses included situations in which energy bills were already included in the rent or in which residents of student housing were unable to view them, creating a blind spot. Regarding information engagement, attitudes were generally positive. 59.9% were willing to learn about energy-saving information or actively trust official information, though 15.6% were disinterested, including 9.6% who found the information too scattered. However, self-assessed knowledge of energy saving remained limited, only 13.1% felt they had a strong understanding and could apply multiple strategies, whereas 36.9% were familiar only with general tips.

In daily energy use, 45.7% prioritised convenience over avoiding hot-water peak times. About 47.5% consistently switched off unused appliances before leaving home, 27.7% sometimes forgot, and 18.1% left devices on standby. Behavioural differences were evident by living pattern, among those living with family (n = 115), 60% actively turned off or reminded others to do so, while 21.7% recognised waste but did not act.

Lifestyle factors also shaped energy use. Microwaves were the most

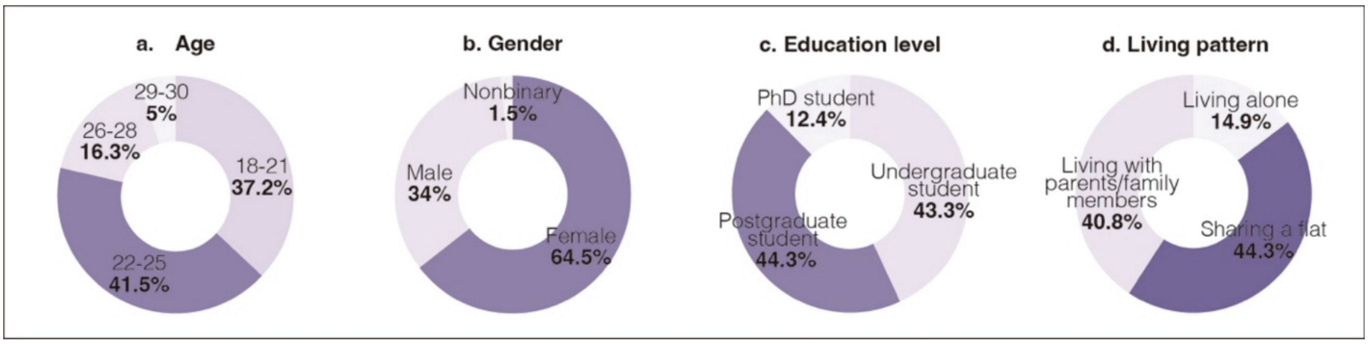

Fig. 5. A–d. demographic background of the sample (n = 282).

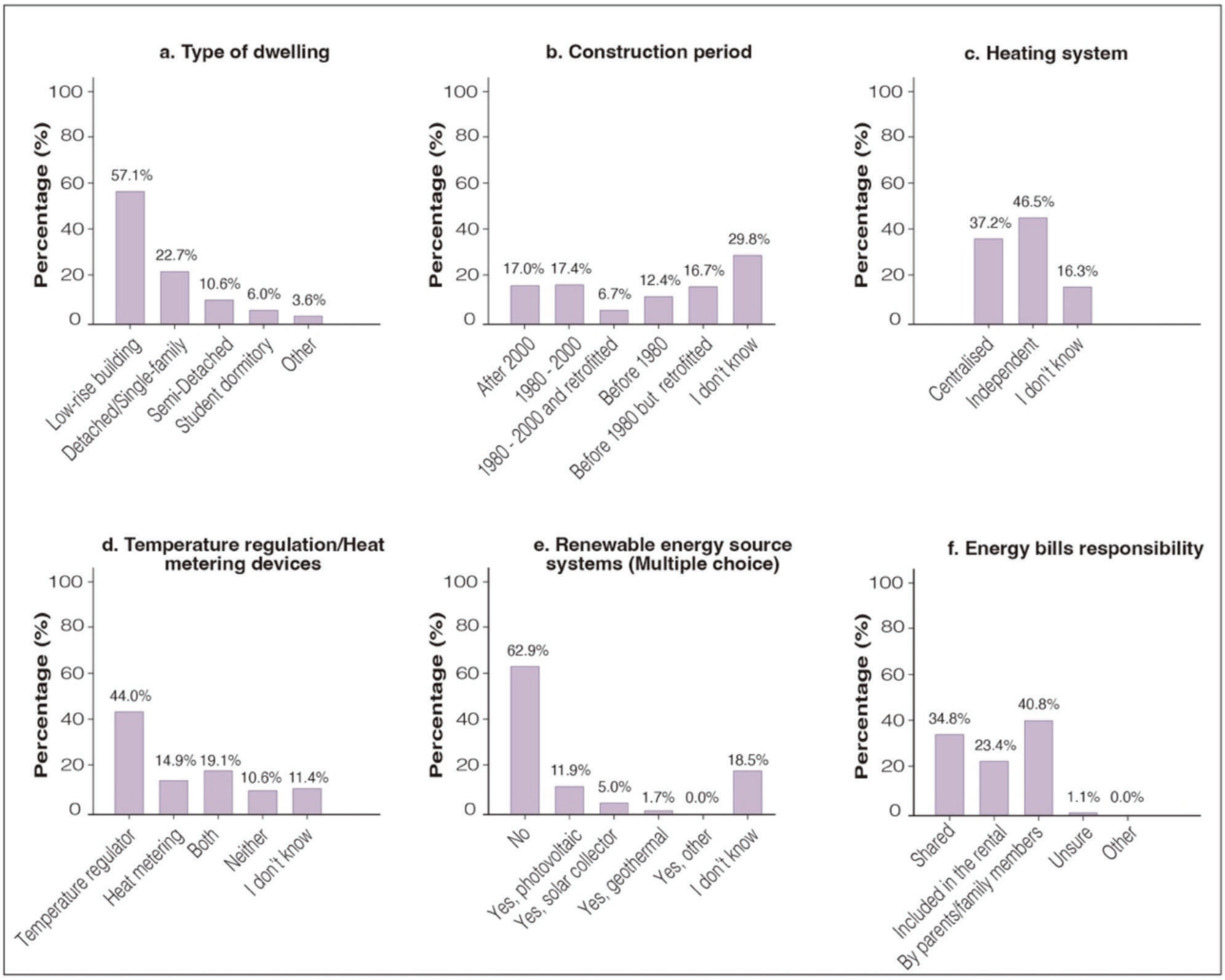

Fig. 6. A–f. building information of the sample (n = 282).

common method for reheating food (48.9%), followed by stoves (19.1%). During mid-season periods, 50.4% chose localised heating or energy-saving modes, and 33.7% adopted non-energy-intensive alternatives (e.g., layering clothes, hot drinks). Only 2.8% heated the entire home, and 6.7% ignored energy-saving settings.

3.3. Psychological factors (Why)

The third dimension explores how psychological factors shaping Gen Z's motivation for energy-saving behaviour (Fig. 7). Regarding attitudes, most respondents expressed active interest in energy-saving topics. Most respondents showed active interest in energy topics: 34.0% participated in discussions and shared experiences, 27.0% preferred listening, and 25.5% engaged selectively. A smaller proportion of students (11%) were seldom or not interested in taking part in such conversations, and 2.5% had never encountered energy-related discussions in their social networks. Around 69.5% indicated a willingness to change daily habits to save energy, with 27.7% even at the cost of convenience and 41.8% through simple. Only 6.4% were unwilling to compromise on comfort or found energy-saving efforts too bothersome.

Regarding SN, an almost overwhelming finding was that around 80.5% of respondents felt that their friends' energy-saving behaviours influenced their own actions, including 25.2% who actively participated and 55.3% who adopted some practices. Only 8.5% reported being unaffected, though still aware of social pressure. PBC also revealed notable trends, 74.1% believed that individual actions were still meaningful. Only 3.2% felt personal efforts had little effect, while 3.5% thought responsibility should lie primarily with policies or industry. A further 1.1% reported giving up due to a lack of collective action. Most respondents showed some degree of moral engagement. About 62.1% reported feeling guilty after wasting energy and were motivated to improve their behaviour. By contrast, 18.8% viewed minor waste as inconsequential, and another 18.8% rarely engaged in self-reflection.

3.4. Situational factors (Act)

The fourth dimension relates to how situational factors influence the actual execution of energy-saving behaviours (Fig. 7). When asked about their investment preferences, 63.8% were willing to pay more for energy-efficient products, with 49.3% who would do so within budget limits. In contrast, only 8.5% preferred cheaper alternatives and 5.7% stated they would not consider such products at all. Incentives were strong motivators for 73.1% of respondents, 36.2% viewed them as "an extra push" and 36.9% as making energy saving "more worthwhile". Only 6.7% felt incentives had little to no effect or would only prompt action in response to minimal requirements. In the open-ended responses, some respondents indicated that they would take energy-saving actions even without incentives (material incentives).

Physical and environmental constraints were also identified as barriers to energy saving. Just 23.8% believed that their current building

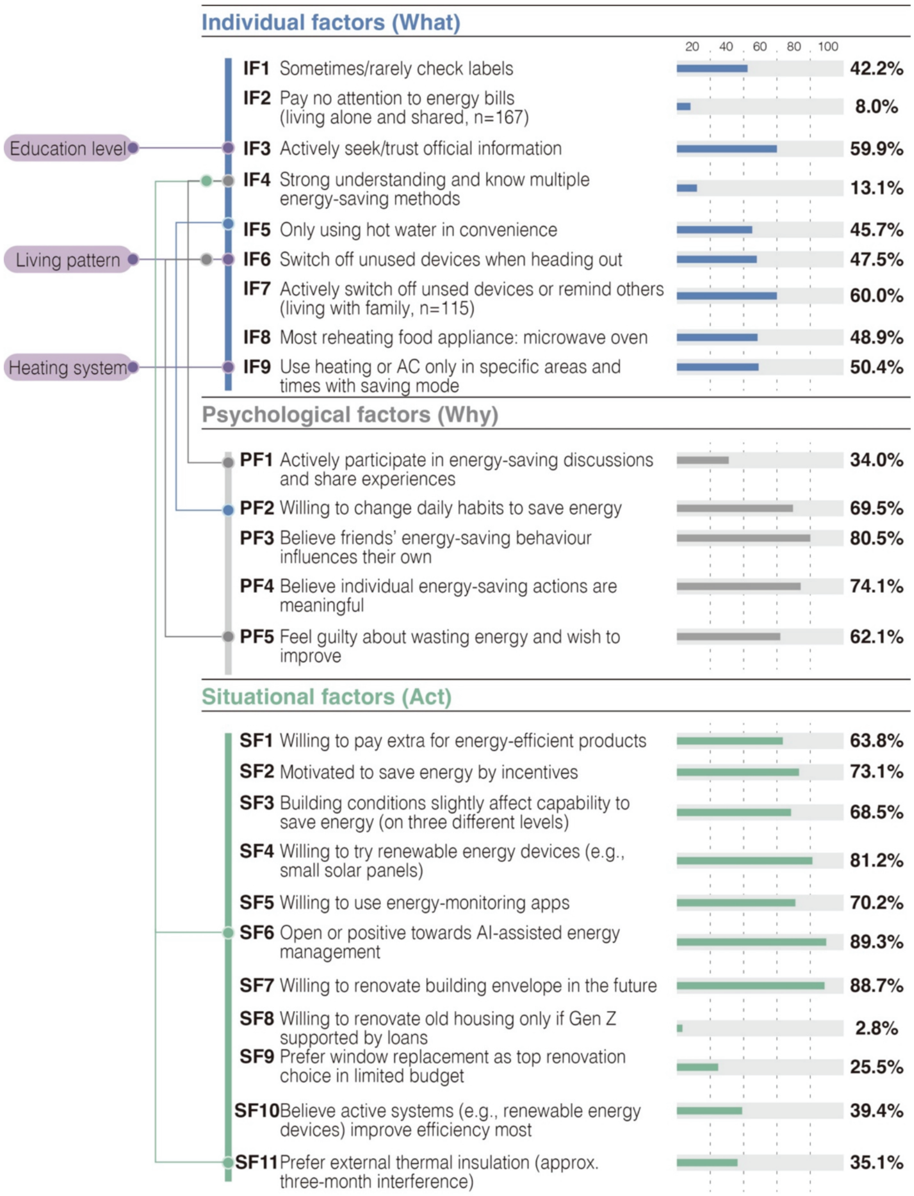

Fig. 7. Key data results and correlations.

conditions had no impact on their efforts; however, 68.5% reported their housing conditions limited energy-saving efforts to varying degrees ("a bit" 36.2%, "somewhat" 24.1%, "a lot" 8.2%).

An interesting finding was Gen Z's marked openness towards technological adoption. A total of 81.2% were willing to try renewable energy devices (e.g., balcony solar panels), with 39.7% more inclined if subsidies or discounts were available. Those who were reluctant cited concerns about equipment maintenance and reliability (11.0%) or a lack of knowledge to assess performance (4.6%). Consideration of the return on investment also appears in "other" option. A similar trend was observed with the energy-monitoring app; 70.2% expressed willingness to use them, and 22.0% admitted they might not sustain long-term engagement. Regarding smart energy management, 89.3% expressed openness or a positive attitude towards AI-assisted systems, including 69.8% who were comfortable with AI taking partial control.

Regarding retrofits, 88.7% supported improvements, and only 1.4% doubted the benefits. However, when offered a hypothetical loan, only 2.8% chose to retrofit existing buildings. Window replacement (25.5%) was the preferred retrofit choice within limited budgets, followed by heating system upgrades (21.6%) and the installation of smart energy monitoring and control systems (21.6%). Additionally, 39.4% believed that active systems (e.g. renewable installations) are more effective in improving energy efficiency than passive upgrades such as paving (26.2%) or window replacement (13.8%). Preferences also varied regarding disruption caused by retrofitting work, with external wall insulation (three-month installation) selected most frequently (35.1%), followed by heat pump upgrades (two to three days; 27.0%).

3.5. Correlation analysis

This section adopts a cross-dimensional perspective to examine the potential interrelationships among several findings. By viewing the four dimensions as an interconnected whole, it critically interprets the dynamic interactions and correlations that shape Gen Z's residential energy behaviours.

Firstly, respondents' levels of education were found to influence their interest in and sources of energy-saving information. As illustrated in Fig. 8a, undergraduate students were more inclined to actively compare different information sources (32.0%), followed by PhD students (28.6%). Postgraduate students demonstrated a stronger

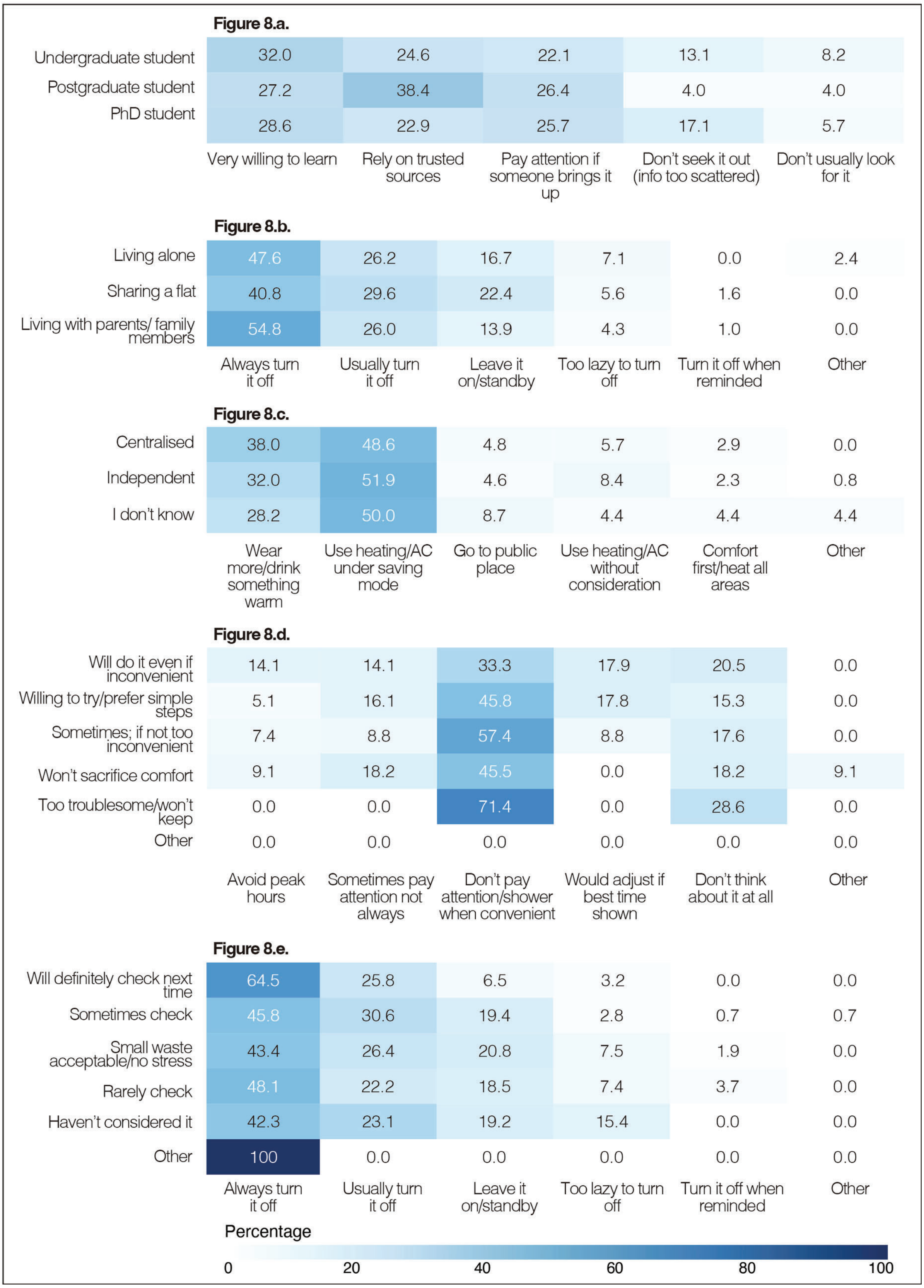

Fig. 8. A–e. results of cross-tabulation analysis.

preference for authoritative sources (38.4%), the highest across all groups. By contrast, PhD students displayed the lowest levels of reliance on official sources (22.9%), with a notable proportion (17.1%) expressing sensitivity to fragmented information. This pattern does not follow a linear trend, suggesting that while education level correlates with information preferences, it does not necessarily enhance proactive learning behaviour.

Secondly, living patterns appeared to influence energy-saving practices (Fig. 8b). Respondents could be classified into three groups: those living alone (n = 42), those sharing accommodation (n = 125), and those living with parents or family members (n = 115). Those living with family exhibited more consistent energy-saving habits, with 54.8% reporting "always turning off unused devices", compared with 47.6% of those living alone and 40.8% of those sharing accommodation. In contrast, the proportion reporting leaving devices in standby mode or "too lazy to switch off" was highest among those in shared housing (28%), followed by those living alone (23.8%). This suggests that shared household norms may foster greater behavioural consistency, whereas greater independence may increase reliance on individual motivation.

Patterns of domestic energy use further revealed that the type of heating system is associated with comfort preferences (Fig. 8c). Regardless of whether heating was centralised or independent, over half of the respondents adopted localised or energy-saving modes (48.6% and 51.9%, respectively). Meanwhile, a higher proportion of respondents with centralised heating adopted passive thermal strategies (e.g., wearing more clothing or drinking hot beverages) (38.0%). Conversely, 8.4% of those with independent heating systems reported ignoring energy considerations entirely, compared with 5.7% of centralised users, suggesting that greater control over heating systems may pose a potential risk of increased consumption.

However, despite generally positive attitudes, behaviour remained strongly conditioned by convenience (Fig. 8d). Among those expressing the strongest willingness to save energy, only 14.1% reported actively avoiding peak hot water usage, while 33.3% showered "whenever convenient", and 20.5% had never considered this issue. A similar pattern emerged among those "willing to take simple measures", with 45.8% prioritising convenience and only 5.1% modifying behaviour to avoid peak demand. In the least motivated group, this tendency was even more pronounced: 71.4% prioritised convenience, and 28.6% had never considered timing at all. Across all groups, convenience remained the dominant factor shaping hot water use, indicating that the translation of intentions into behaviour is still limited by practical costs and lifestyle.

As shown in Fig. 8e, PMNs played a notable role in stabilising energy-saving behaviour. Among respondents who reported feeling guilty about wasting energy, 64.5% always switched off unused devices, compared with just 42.3% in the group that reported no guilt. Conversely, only 3.2% of the high-guilt group admitted to being "too lazy to switch off", compared with 15.4% of the low-guilt group. These findings highlight the stabilising and regulative role of PMNs in sustaining energy-saving behaviour.

Notably, self-reported knowledge levels were found to influence not only the likelihood of participating in energy-related discussions but also several behavioural choices (Fig. 9a). Based on respondents' self-assessment, three levels of knowledge were identified: high (strong understanding and know quite a bit), medium (know some general tips), and low (know very little and no understanding at all). Among those in the high-knowledge group, 61.5% reported actively engaging in energy-saving discussions and sharing experience, although 42.9% simultaneously noted that such discussions rarely occurred within their social

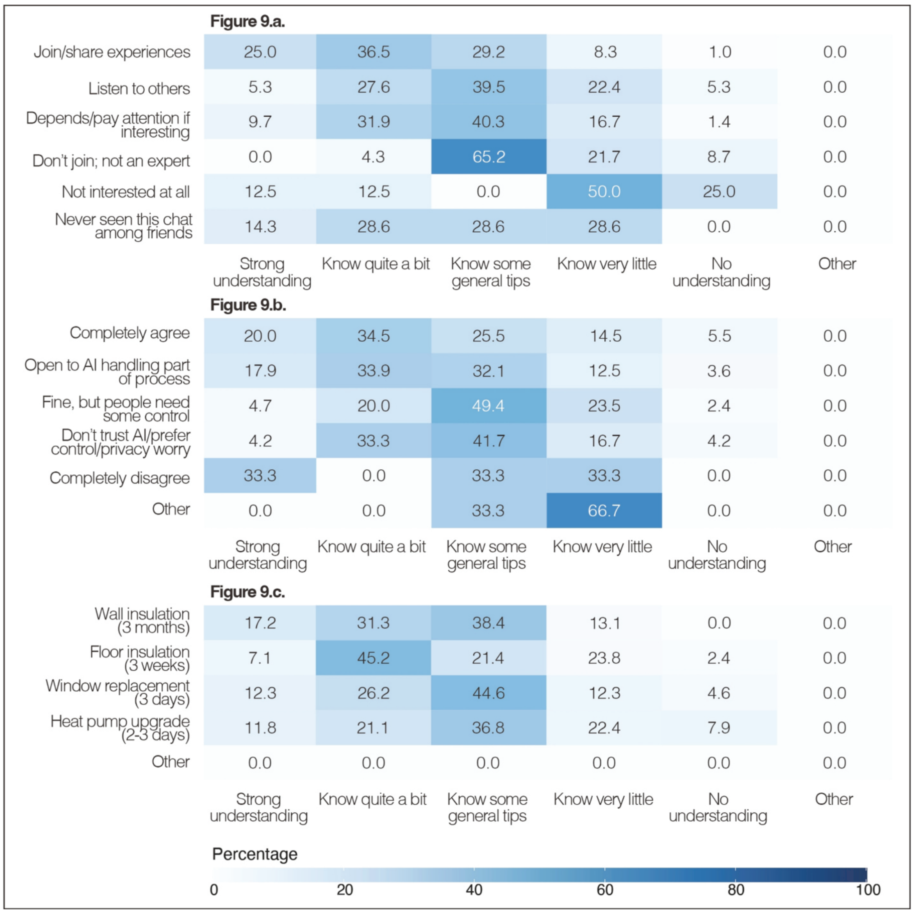

Fig. 9. A–c. results of cross-tabulation analysis.

circles. In contrast, the medium-knowledge group tended to adopt a more passive role, with 39.5% preferring to listen and 40.3% engaging only when the topic captured their interest. Meanwhile, 75% of the low-knowledge group expressed limited interest or avoided discussions due to "not feeling knowledgeable enough" (30.4%). These findings suggest that a higher knowledge level is associated with a greater willingness to engage in energy-related discourse, whereas a perceived lack of expertise may lead to withdrawal.

A related result emerged regarding respondents' trust in Artificial Intelligence (AI)-based energy management systems (Fig. 9b). Those who expressed full or partial trust in AI tended to report higher levels of energy knowledge. In both groups, over half identified as having high knowledge (54.5% and 51.8%, respectively). As trust in AI tools decreased, so too did self-reported knowledge levels. Among those who emphasised retaining human control or expressed scepticism towards AI, the share of respondents with medium or low knowledge rose considerably (49.4% and 23.5%, respectively). This result shows that a higher knowledge level is associated with greater openness to smart energy management technologies.

A similar trend was observed in preferences for renovation measures with differing levels of disruption (Fig. 9c). Respondents in the high-knowledge group were more willing to accept longer-duration interventions: 17.2% ("strong understanding") and 31.3% ("know quite a bit") favoured external wall insulation (3 months), while these two groups, 7.1% and 45.2% supported floor insulation (3 weeks), both considerably higher than in other knowledge tiers. By comparison, those with medium knowledge levels showed a clear preference for moderate-disruption, short-duration measures, such as window replacement (3 days), which was selected by 44.6%. Conversely, the share of respondents favouring heat pump upgrades (2–3 days) increased significantly among the low-knowledge group, with 22.4% ("know very little") and 7.9% ("no understanding"). Thus, individuals with a lower knowledge level may face evaluative barriers when considering more technically complex or longer-term retrofit measures.

4. Discussion

This study reported a user-centred gamified approach to investigate the key factors influencing Gen Z's residential energy use and their inclinations toward building retrofits and energy technology adoption. The findings reveal behavioural patterns and dynamic interconnections across four dimensions: sociodemographic, individual, psychological, and situational factors, highlighting the potential leverage derived from the correlation, and how these differ from those commonly observed among adult populations.

4.1. Enhancing the visibility and readability of energy information

Although Gen Z is often portrayed as a generation highly environmentally conscious [96], previous studies have largely treated it as a homogeneous group. However, the findings of this study indicate a marked heterogeneity in energy-saving behaviour, which must be interpreted in relation to specific sociodemographic contexts.

First, participants demonstrated a knowledge gap regarding the energy performance of their dwellings: about one-third were unaware of their dwelling's construction year, and many could not identify their heating or metering systems. This blind spot likely stems from the prevalence of rental or shared housing in the sample, which limits visibility into building energy performance. Since building visibility is positively associated with occupants' willingness to undertake energy-saving interventions [97], limited information access may distort young occupants' willingness to adopt energy-saving measures, leading to overly optimistic/pessimistic assessments of the effectiveness of their own energy-saving capabilities. When billing responsibilities or device control are decentralised, individuals often lack the feedback needed to connect their actions to energy consumption [98]. Interestingly, respondents with independent heating systems were more likely to use heating without energy-saving modes, suggesting that autonomy without clear feedback may encourage wasteful use. However, compared to knowledge gain, real-time feedback is more effective in driving reductions in energy consumption [99], and tailored information and feedback can reduce direct energy consumption by at least 5% [100]. Furthermore, although young people living alone or in shared accommodation were sensitive to energy costs, over half did not actively analyse their energy bills, likely due to complex wording and limited explanatory content that hindered behavioural interpretation [101]. Therefore, among young people, the form of information feedback is particularly important, especially since Gen Z is affected by instant information than previous generations.

4.2. Providing tiered behaviour guidance strategies

Living with family members exhibited more consistent energy-saving habits, in line with previous research [102], while living alone or in shared housing showed greater behavioural variability, especially in collective living situations. Wang et al. [124] reported that behaviour in shared environments is more susceptible to peers' norms, actions, and communication. As independent living becomes increasingly common among Gen Z, traditional family-based strategies for energy intervention may no longer be applicable in all situations. Future policies must therefore adapt to diverse and flexible living arrangements among young adults [103].

Although prior studies have suggested that higher education levels may promote engagement with sustainable energy topics [104]. This study reveals that the relationship is not necessarily linear. A higher level of education does not always translate into a stronger inclination to seek energy-related knowledge actively. Instead, education appears to shape preferred information sources rather than directly enhancing knowledge acquisition. This finding echoes the conclusion of Mills and Schleich that energy knowledge is not solely determined by education, but is influenced by other factors [48]. Thus, energy communication strategies should not assume behavioural potential based on education alone. More promising approaches may lie in tailoring educational content based on user profiles, including personal background, information preferences, and technological familiarity. Such simplified, step-based interventions are easier to implement and facilitate faster decision-making, which is particularly crucial for young individuals whose energy practices are still being formed.

4.3. Conducting scenario-based energy-saving education and activities

The findings reveal a critical gap at the individual factor level. Although Gen Z exhibits high awareness of energy efficiency, this attitude does not consistently translate into energy-saving habits or residential practices. This aligns with the scientific literature [105], indicating that awareness alone, even with supportive policies, cannot ensure behavioural change. For example, most respondents prioritised convenience over avoiding hot-water peak times despite expressing willingness to modify habits. These patterns show that, for young users, ease of implementation outweighs methodological accuracy. However, convenience-driven choices are common in household energy use [106], especially among younger populations, they should not be interpreted as behavioural failure [107]. Their high level of awareness laid a solid foundation and the key to a feasible solution lies in lowering the barriers to energy-saving actions and providing clear instructions [107].

Psychological factors further shape behavioural intention. According to the TPB, attitudes are necessary but insufficient for action; PBC and SN are equally critical [108]. While Gen Z respondents were influenced by subjective norms, especially peers' energy-saving behaviour, their sense of behavioural control was weak, reflected in limited knowledge and low confidence. Correlation analysis showed that willingness to engage in energy-related discussions declined among those with lower self-perceived knowledge. Unlike elderly adults, information spreads much faster among Gen Z, who maintain far closer and more immediate social connections. Breaking this negative loop requires interventions combining cognitive and social mechanisms, such as low-threshold knowledge competitions, peer-led discussions, and interactive group incentives, to enhance energy literacy and sustained engagement. In addition, schools/universities should offer courses on energy use, energy consumption, and guidance on energy conservation; however, such programs are not common [49,52]. On the other hand, PMN also demonstrated stability in maintaining behaviour. Some research suggests an effect that tends to be more pronounced among highly educated groups [88]. Education and awareness campaigns thus offer not only informational benefits but also value-shaping effects that reinforce users' sense of responsibility [109].

4.4. Developing user-centred digital tools and incentive mechanisms

Contextual constraints significantly influence Gen Z's energy-saving behaviour. Yang et al. found that economic costs have the greatest impact on young people with low consumption levels [110]. Although the majority expressed willingness to pay more for high-efficiency products, limited purchasing power and uncertain long-term returns hindered adoption. Meanwhile, the results showed that respondents generally recognised incentives (such as subsidies and rewards) as triggers for action. Providing economic (material) and social (publicity and encouragement) incentives can increase the willingness to engage in energy-saving behaviour. However, He et al. [111] caution that financial incentives often yield short-term effects and may undermine intrinsic motivation. Social incentives offer greater potential for long-term habit formation [112]. It is worth noting that informational interventions are more effective than economic interventions for Gen Z individuals with lower energy cost burdens (e.g., dormitory) [113]. Thus, incentive design should adapt to user contexts, combining financial stimuli at the initiation stage with social recognition mechanisms (e.g., public acknowledgement or community ranking) during behavioural maintenance.

Furthermore, this study observed that most users believed their energy-saving capabilities were limited to varying degrees by the physical environment. While subjective norms strongly influence Gen Z, they foster consistent energy-saving behaviour only in energy-efficient living conditions [62]. Many participants expressed interest in adopting renewable or smart energy technologies but cited concerns about maintenance, reliability, and usability. This illustrates that simply providing technology is insufficient to increase adoption rates. The key issue in technology adoption today is not a lack of advanced technology, but rather the inability to ascertain whether users possess the necessary understanding to adopt energy-saving technologies. In other words, consumers' perceptions of technology influence their judgments of its value, thereby affecting their willingness to adopt it [114]. Correlation analysis reinforced this finding: users with higher self-perceived energy knowledge were more willing to adopt smart tools. However, one thing is quite certain that Gen Z is better at using digital tools than any previous generation [105], which presents a promising opportunity for developing such tools. Future strategies should match retrofit and digital tools to users' skill levels and provide progressive deployment pathways. The survey results show that Gen Z generally has a high willingness to retrofit buildings for energy efficiency. Still, their limited professional knowledge may hinder their ability to adopt complex energy-saving measures. Therefore, it is necessary to strengthen user support mechanisms such as highly understandable technology demonstrations, step-by-step energy-saving guidelines, and digital simulation tools to bridge the knowledge gap.

5. Key insights, limitations and future prospects

This study addressed the three research questions and offered key insights into Gen Z's behavioural patterns and energy use leverage. First, Gen Z's residential energy behaviour is heterogeneous and shaped by multiple factors. Sociodemographic characteristics influence behavioural differences, while convenience and established habits determine the feasibility of energy-saving actions. Subjective norms may have a multiplier effect in this generation, enabling rapid diffusion of socially shared practices. Situation factors, such as incentives and housing conditions, can amplify or restrain behaviour (RQ1). Second, while most respondents were open to energy-saving measures and building retrofits, their levels of knowledge were highly uneven. Those with lower self-perceived knowledge showed higher cognitive and practical barriers during adoption (RQ2). Finally, although intentions to adopt energy technologies and retrofit measures were generally high, contextual constraints, including cost, physical conditions, implementation burden, and technical understanding, impeded the translation of intentions into action (RQ3).

Despite the positive results, the study has some limitations. First, the survey sample consisted mainly of university students at UNIBO, which relates to the city's predominantly student population but also limits the broad applicability of the findings. Future research should include a more diverse range of Gen Z members, including those under 18, young professionals, and young adults who have formed independent households, to capture variations in energy behaviour across different life stages. Such expansion would enhance both the robustness and generalisability of the findings. Furthermore, the cross-sectional design of this study limits its ability to capture the temporal dynamics of the relationship between energy-saving intentions and actual behaviour. Future studies could incorporate real energy consumption data or behavioural tracking tools to further validate the effectiveness of the proposed behavioural levers.

Overall, these limitations offer clear avenues for future research, helping to deepen the insights generated here and ultimately support the development of more effective strategies for engaging the next generation of energy users.

6. Conclusion

Compared with previous studies that focused on a single perspective (such as technological performance, behavioural motivation and sociodemographic), this research adopts an interdisciplinary approach to examine multiple factors influencing Gen Z's residential energy behaviour, drawing on data from a gamified investigation. Based on the findings, several promising leverage points are proposed to support future decision-making and policy development.

The results indicate that although Gen Z generally holds positive attitudes towards energy-saving, this awareness does not consistently translate into practice. Enhancing the visibility and clarity of energy information is therefore crucial. User-friendly feedback systems that show the major sources of energy consumption and provide personalised saving recommendations could help young users understand the link between their actions and energy use.

Developing tiered behavioural guidance that accounts for differences in personal background, daily routines, and technological literacy would also help reduce barriers to action. Energy education and communication are essential levers as well. Policymakers should prioritise embedding energy knowledge into contexts relevant to Gen Z's daily life, rather than relying on abstract slogans or policy directives, to strengthen awareness and understanding in meaningful situations.

Finally, given Gen Z's digitally oriented environment, designing user-centred energy-saving tools and platforms that incorporate real-time feedback, incentives, and social interaction can help reduce knowledge and skill barriers, thereby fostering long-term engagement in sustainable behaviour.

In summary, no single strategy can address the diversity of Gen Z's residential energy behaviour. Effective behavioural levers must integrate knowledge, technology, psychological, and situational dimensions within a multi-layered facilitation framework. A user-centred approach that aligns strategies with users' needs can empower young people and accelerate the transition to lower-carbon residential energy use.

CRediT authorship contribution statement

Yehui Peng: . **Lia Marchi:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis. **Jacopo Gaspari:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

[1] Creutzig, F., J. Roy, P. Devine-Wright, J. Díaz-José, F.W. Geels, A. Grubler, N. Maïzi, E. Masanet, Y. Mulugetta, C.D. Onyige, P.E. Perkins, A. Sanches-Pereira, E. U. Weber, 2022: Demand, services and social aspects of mitigation. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.007.

[2] D. Zhao, A.P. McCoy, J. Du, P. Agee, Y. Lu, Interaction effects of building technology and resident behavior on energy consumption in residential buildings, Energy Build. 134 (2017) 223–233, https://doi.org/10.1016/j.enbuild.2016.10.049.

[3] European Commission, Energy efficiency directive, Energy Efficiency Directive (n.d.). https://energy.ec.europa.eu/topics/energy-efficiency/energy-efficiency-targets-directive-and-rules/energy-efficiency-directive_en (accessed July 12, 2025).

[4] United Nations Development Programme, What is the sustainable energy transition and why is it key to tackling climate change?, UNDP Climate Promise (2025). https://climatepromise.undp.org/news-and-stories/what-sustainable-energy-transition-and-why-it-key-tackling-climate-change (accessed July 10, 2025).

[5] European Commission, Energy Performance of Buildings Directive, Energy Performance of Buildings Directive (n.d.). https://energy.ec.europa.eu/topics/energy-efficiency/energy-performance-buildings/energy-performance-buildings-directive_en (accessed July 10, 2025).

[6] International Energy Agency, Buildings, Buildings (2023). https://www.iea.org/energy-system/buildings (accessed July 12, 2025).

[7] S. Bouckaert, A.F. Pales, C. McGlade, U. Remme, B. Wanner, L. Varro, D. D'Ambrosio, T. Spencer, Net zero by 2050: A roadmap for the global energy sector, Int. Energy Agency (2021) accessed March 4, 2026.

[8] J. Gaspari, E. Antonini, L. Marchi, V. Vodola, Energy transition at home: a survey on the data and practices that lead to a change in household energy behavior, Sustainability 13 (2021) 5268, https://doi.org/10.3390/su13095268.

[9] D. Yan, W. O'Brien, T. Hong, X. Feng, H. Burak Gunay, F. Tahmasebi, A. Mahdavi, Occupant behavior modeling for building performance simulation: current state and future challenges, Energy Build. 107 (2015) 264–278, https://doi.org/10.1016/j.enbuild.2015.08.032.

[10] R. Galvin, Making the 'rebound effect' more useful for performance evaluation of thermal retrofits of existing homes: defining the 'energy savings deficit' and the 'energy performance gap, Energy Build. 69 (2014) 515–524, https://doi.org/10.1016/j.enbuild.2013.11.004.

[11] D. Calì, T. Osterhage, R. Streblow, D. Müller, Energy performance gap in refurbished german dwellings: lesson learned from a field test, Energy Build. 127 (2016) 1146–1158, https://doi.org/10.1016/j.enbuild.2016.05.020.

[12] A. Paone, J.-P. Bacher, The impact of building occupant behavior on energy efficiency and methods to influence it: a review of the state of the art, Energies 11 (2018) 953, https://doi.org/10.3390/en11040953.

[13] H.T. Ebuy, H. Bril El Haouzi, R. Benelmir, R. Pannequin, Occupant behavior impact on building sustainability performance: a literature review, Sustainability 15 (2023) 2440, https://doi.org/10.3390/su15032440.

[14] A. Levesque, R.C. Pietzcker, G. Luderer, Halving energy demand from buildings: the impact of low consumption practices, Technol. Forecast. Soc. Chang. 146 (2019) 253–266, https://doi.org/10.1016/j.techfore.2019.04.025.

[15] X. Liu, Q. Wang, H.-H. Wei, H.-L. Chi, Y. Ma, I.Y. Jian, Psychological and demographic factors affecting household energy-saving intentions: a TPB-based study in northwest China, Sustainability 12 (2020) 836, https://doi.org/10.3390/su12030836.

[16] K. Zhou, S. Yang, Understanding household energy consumption behavior: the contribution of energy big data analytics, Renew. Sustain. Energy Rev. 56 (2016) 810–819, https://doi.org/10.1016/j.rser.2015.12.001.

[17] X. Liu, Q.-C. Wang, I.Y. Jian, H.-L. Chi, D. Yang, E.-H.-W. Chan, Are you an energy saver at home?, in: The Personality Insights of Household Energy Conservation Behaviors Based on Theory of Planned Behavior, Resources, Conservation and Recycling, 2021 105823, https://doi.org/10.1016/j.resconrec.2021.105823.

[18] K.L. Fingerman, K.A. Pillemer, M. Silverstein, J.J. Suitor, The baby boomers' intergenerational relationships, Gerontologist 52 (2012) 199–209, https://doi.org/10.1093/geront/gnr139.

[19] P.S. Norum, Examination of generational differences in household apparel expenditures, Fam. Consum. Sci. Res. J. 32 (2003) 52–75, https://doi.org/10.1177/1077727X03255901.

[20] R. Bardazzi, M.G. Pazienza, When I was your age: generational effects on long-run residential energy consumption in Italy, Energy Res. Soc. Sci. 70 (2020) 101611, https://doi.org/10.1016/j.erss.2020.101611.

[21] R. Bardazzi, M.G. Pazienza, in: Switch off the Light, please! Energy Use, Aging Population and Consumption Habits, Energy Economics, 2017, pp. 161–171, https://doi.org/10.1016/j.eneco.2017.04.025.

[22] E. Colli, Towards a mobility transition? Understanding the environmental impact of millennials and baby boomers in europe, Travel Behaviour and Society 20 (2020) 273–289. https://doi.org/10.1016/j.tbs.2020.03.013.

[23] M. Dimock, Defining generations: Where Millennials end and Generation Z begins, Pew Research Center (2019). https://www.pewresearch.org/short-reads/2019/01/17/where-millennials-end-and-generation-z-begins/ (accessed November 17, 2025).

[24] McCrindle, Understanding Generation Alpha, McCrindle (2022). https://mccrindle.com.au/article/topic/generation-alpha/generation-alpha-defined/ (accessed September 22, 2025).

[25] B. Barhate, K.M. Dirani, Career aspirations of generation Z: a systematic literature review, Eur. J. Train. Develop. 46 (2021) 139–157, https://doi.org/10.1108/EJTD-07-2020-0124.

[26] K. Gabrielova, A.A. Buchko, Here comes generation Z: Millennials as managers, Bus. Horiz. 64 (2021) 489–499, https://doi.org/10.1016/j.bushor.2021.02.013.

[27] C. Seemiller, M. Grace, Generation Z: Educating and engaging the next generation of students, About Campus 22 (2017) 21–26, https://doi.org/10.1002/abc.21293.

[28] C.L. Thigpen, A. Tyson, On social media, Gen Z and Millennial adults interact more with climate change content than older generations, Pew Research Center (2021). https://www.pewresearch.org/short-reads/2021/06/21/on-social-media-gen-z-and-millennial-adults-interact-more-with-climate-change-content-than-older-generations/ (accessed July 13, 2025).

[29] A. Tantau, S.I. Goia (Agoston), V.M. Dincă, C. Păunescu, S. Stamule, T. Stamule, A. Bogdan, Exploring the generation Z attitude towards energy efficiency improvement and decarbonization through heat pumps: An empirical study in Romania, Sustainability 16 (2024) 1250, https://doi.org/10.3390/su16031250.

[30] L. Cerović, A. Malnar, D. Sinčić, Energy literacy of economics students in rijeka: Knowledge, attitudes, and behavioral approach, Energies 17 (2024) 1840, https://doi.org/10.3390/en17081840.

[31] F. Hoque, R.M. Yasin, K. Sopian, Revisiting education for sustainable development: Methods to inspire secondary school students toward renewable energy, Sustainability 14 (2022) 8296, https://doi.org/10.3390/su14148296.

[32] IPCC, 2023: Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, H. Lee and J. Romero (eds.)]. IPCC, Geneva, Switzerland, 184 pp., doi: 10.59327/IPCC/AR6-9789291691647.

[33] R.J. Fisher, Social desirability bias and the validity of indirect questioning, J. Consum. Res. 20 (1993) 303–315, https://doi.org/10.1086/209351.

[34] D. Schwartz, B. Fischhoff, T. Krishnamurti, F. Sowell, The hawthorne effect and energy awareness, in: Proceedings of the National Academy of Sciences, 2013, pp. 15242–15246, https://doi.org/10.1073/pnas.1301687110.

[35] L. Steg, Promoting household energy conservation, Energy Policy 36 (2008) 4449–4453, https://doi.org/10.1016/j.enpol.2008.09.027.

[36] C.-Y. Zhang, B. Yu, J.-W. Wang, Y.-M. Wei, Impact factors of household energy-saving behavior: an empirical study of shandong province in China, J. Clean. Prod. 185 (2018) 285–298, https://doi.org/10.1016/j.jclepro.2018.02.303.

[37] Z. Ding, G. Wang, Z. Liu, R. Long, Research on differences in the factors influencing the energy-saving behavior of urban and rural residents in China–a case study of Jiangsu province, Energy Policy 100 (2017) 252–259, https://doi.org/10.1016/j.enpol.2016.10.013.

[38] Z. Ding, X. Jiang, Z. Liu, R. Long, Z. Xu, Q. Cao, Factors affecting low-carbon consumption behavior of urban residents: a comprehensive review, Resour. Conserv. Recycl. 132 (2018) 3–15, https://doi.org/10.1016/j.resconrec.2018.01.013.

[39] T. Yue, R. Long, H. Chen, Factors influencing energy-saving behavior of urban households in Jiangsu Province, Energy Policy 62 (2013) 665–675, https://doi.org/10.1016/j.enpol.2013.07.051.

[40] Y. Liu, R. Liu, X. Jiang, What drives low-carbon consumption behavior of Chinese college students? The Regulation of Situational Factors, Nat Hazards 95 (2019) 173–191, https://doi.org/10.1007/s11069-018-3497-3.

[41] F. Belaïd, T. Garcia, Understanding the spectrum of residential energy-saving behaviours: French evidence using disaggregated data, Energy Econ. 57 (2016) 204–214, https://doi.org/10.1016/j.eneco.2016.05.006.

[42] N. Rainisio, M. Boffi, L. Pola, P. Inghilleri, I. Sergi, M. Liberatori, The role of gender and self-efficacy in domestic energy saving behaviors: a case study in Lombardy, Italy, Energy Policy 160 (2022) 112696, https://doi.org/10.1016/j.enpol.2021.112696.

[43] A.D. Paço, L. Varejão, Factors affecting energy saving behaviour: a prospective research, J. Environ. Plan. Manag. 53 (2010) 963–976, https://doi.org/10.1080/09640568.2010.495489.

[44] S. Yang, Y. Zhang, D. Zhao, Who exhibits more energy-saving behavior in direct and indirect ways in China? The role of psychological factors and socio-demographics, Energy Policy 93 (2016) 196–205, https://doi.org/10.1016/j.enpol.2016.02.018.

[45] E. Azar, H. Al Ansari, Framework to investigate energy conservation motivation and actions of building occupants: the case of a green campus in Abu Dhabi, UAE, Appl. Energy 190 (2017) 563–573, https://doi.org/10.1016/j.apenergy.2016.12.128.

[46] C.J. Brown, N. Markusson, The responses of older adults to smart energy monitors, Energy Policy 130 (2019) 218–226, https://doi.org/10.1016/j.enpol.2019.03.063.

[47] J. Du, W. Pan, Examining energy saving behaviors in student dormitories using an expanded theory of planned behavior, Habitat Int. 107 (2021) 102308, https://doi.org/10.1016/j.habitatint.2020.102308.

[48] B. Mills, J. Schleich, Residential energy-efficient technology adoption, energy conservation, knowledge, and attitudes: an analysis of European countries, Energy Policy 49 (2012) 616–628, https://doi.org/10.1016/j.enpol.2012.07.008.

[49] C. Vogiatzi, G. Gemenetzi, L. Massou, S. Poulopoulos, S. Papaefthimiou, E. Zervas, Energy use and saving in residential sector and occupant behavior: a case study in Athens, Energy Build. 181 (2018) 1–9, https://doi.org/10.1016/j.enbuild.2018.09.039.

[50] L. Poruschi, C.L. Ambrey, On the confluence of city living, energy saving behaviours and direct residential energy consumption, Environ. Sci. Policy 66 (2016) 334–343, https://doi.org/10.1016/j.envsci.2016.07.003.

[51] A. Kollmuss, J. Agyeman, Mind the Gap: why do people act environmentally and what are the barriers to pro-environmental behavior? Environ. Educ. Res. 8 (2002) 239–260, https://doi.org/10.1080/13504620220145401.

[52] S. Zhao, Q. Song, C. Wang, Characterizing the energy-saving behaviors, attitudes and awareness of university students in Macau, Sustainability 11 (2019) 6341, https://doi.org/10.3390/su11226341.

[53] M.J. Polonsky, A. Vocino, S.L. Grau, R. Garma, A.S. Ferdous, The impact of general and carbon-related environmental knowledge on attitudes and behaviour of US consumers, J. Mark. Manag. 28 (2012) 238–263, https://doi.org/10.1080/0267257X.2012.659279.

[54] D. Brounen, N. Kok, J.M. Quigley, Energy literacy, awareness, and conservation behavior of residential households, Energy Econ. 38 (2013) 42–50, https://doi.org/10.1016/j.eneco.2013.02.008.

[55] A. Paço, T. Lavrador, Environmental knowledge and attitudes and behaviours towards energy consumption, J. Environ. Manage. 197 (2017) 384–392, https://doi.org/10.1016/j.jenvman.2017.03.100.

[56] H. Elsharkawy, P. Rutherford, Energy-efficient retrofit of social housing in the UK: Lessons learned from a community energy saving programme (CESP) in nottingham, Energ. Buildings 172 (2018) 295–306, https://doi.org/10.1016/j.enbuild.2018.04.067.

[57] T.F. Sanquist, H. Orr, B. Shui, A.C. Bittner, Lifestyle factors in U.S. residential electricity consumption, Energy Policy 42 (2012) 354–364, https://doi.org/10.1016/j.enpol.2011.11.092.

[58] J.W.C. Lee, A. Tanusia, Energy conservation behavioural intention: attitudes, subjective norm and self-efficacy, IOP Conf. Ser.: Earth Environ. Sci. 40 (2016) 012087, https://doi.org/10.1088/1755-1315/40/1/012087.

[59] F. Rasool, N.A. Zuberi, N.U. Siddiqui, M. Madni, Using the theory of plan behavior and norm activation model to understand individual energy conservation behavior in karachi, pakistan: using the theory of plan behavior and norm activation model to understand individual energy conservation behavior in karachi, pakistan, IJEEG 10 (2019) 93–99.

[60] H.C. Hou, K.K. Law, Examining the relationship between student residents' self-reported energy consumption behavior and their energy-saving intention, J. Build. Eng. 98 (2024) 111490, https://doi.org/10.1016/j.jobe.2024.111490.

[61] Examining the relationship between student residents' self-reported energy consumption behavior and their energy-saving intention, Journal of Building Engineering 98 (2024) 111490. https://doi.org/10.1016/j.jobe.2024.111490.

[62] C. Boomsma, R.V. Jones, S. Pahl, A. Fuertes, Do psychological factors relate to energy saving behaviours in inefficient and damp homes? A study among English social housing residents, Energy Res. Soc. Sci. 47 (2019) 146–155, https://doi.org/10.1016/j.erss.2018.09.007.

[63] C.-S. Tan, H.-Y. Ooi, Y.-N. Goh, A moral extension of the theory of planned behavior to predict consumers' purchase intention for energy-efficient household appliances in Malaysia, Energy Policy 107 (2017) 459–471, https://doi.org/10.1016/j.enpol.2017.05.027.

[64] J. Zhang, L. Ma, J. Li, Why low-carbon publicity effect limits? The role of heterogeneous intention in reducing household energy consumption, Energies 14 (2021) 7634, https://doi.org/10.3390/en14227634.

[65] S. Lindenberg, L. Steg, Normative, gain and hedonic goal frames guiding environmental behavior, J. Soc. Issues 63 (2007) 117–137, https://doi.org/10.1111/j.1540-4560.2007.00499.x.

[66] L. Steg, C. Vlek, Encouraging pro-environmental behaviour: an integrative review and research agenda, J. Environ. Psychol. 29 (2009) 309–317, https://doi.org/10.1016/j.jenvp.2008.10.004.

[67] T. Hoppe, F.H.J.M. Coenen, M.T. Bekendam, Renewable energy cooperatives as a stimulating factor in household energy savings, Energies 12 (2019) 1188, https://doi.org/10.3390/en12071188.

[68] H.W. Kua, S.E. Wong, Lessons for integrated household energy conservation policies from an intervention study in Singapore, Energy Policy 47 (2012) 49–56, https://doi.org/10.1016/j.enpol.2012.04.009.

[69] I. Kousis, M. Laskari, V. Ntouros, M.-N. Assimakopoulos, J. Romanowicz, An analysis of the determining factors of fuel poverty among students living in the private-rented sector in Europe and its impact on their well-being, Energy Sources Part B 15 (2020) 113–135, https://doi.org/10.1080/15567249.2020.1773579.

[70] H. Cynthia Hou, Occupants' willingness to reduce in-room energy consumption – a discrete choice experiment (DCE) approach with occupants in a student apartment, Energy Build. 320 (2024) 114628, https://doi.org/10.1016/j.enbuild.2024.114628.

[71] S. Paiho, H. Ahvenniemi, Non-technical barriers to energy efficient renovation of residential buildings and potential policy instruments to overcome them—evidence from young Russian adults, Buildings 7 (2017) 101, https://doi.org/10.3390/buildings7040101.

[72] S. Bouzarovski, S. Petrova, S. Tirado-Herrero, From fuel poverty to energy vulnerability: the importance of services, needs and practices, SSRN J. (2014), https://doi.org/10.2139/ssrn.2743143.

[73] V. Brakovska, A. Blumberga, The influence of young people on household decisions on energy efficiency in Latvia, Environ. Clim. Technol. 28 (2024) 45–57, https://doi.org/10.2478/rtuect-2024-0005.

[74] S. Hu, D. Yan, B. Dong, J. Fu, Exploring key factors impacting cooling usage patterns of Chinese urban household based on a large-scale questionnaire survey, Energy Build. 214 (2020) 109885, https://doi.org/10.1016/j.enbuild.2020.109885.

[75] N. Eslamnoor, S.M. Vural, User behavior and energy efficiency in north cyprus university dormitories: a case study, J. Hous. Built. Environ. 37 (2022) 1159–1178, https://doi.org/10.1007/s10901-021-09878-1.

[76] T. Zhou, X. Luo, X. Liu, G. Liu, N. Li, Y. Sun, M. Xing, J. Liu, Analysis of the influence of the stay-at-home order on the electricity consumption in Chinese university dormitory buildings during the COVID-19 pandemic, Energy Build. 277 (2022) 112582, https://doi.org/10.1016/j.enbuild.2022.112582.

[77] A. Rinaldi, M. Schweiker, F. Iannone, On uses of energy in buildings: Extracting influencing factors of occupant behaviour by means of a questionnaire survey, Energy Build. 168 (2018) 298–308, https://doi.org/10.1016/j.enbuild.2018.03.045.

[78] R. Vathy, M. Rosenthal, J.M. Ballou, College student behaviors and preferences in community pharmacies, J. Am. Coll. Health 73 (2025) 430–434, https://doi.org/10.1080/07448481.2023.2217725.

[79] Z. Deme Belafi, T. Hong, A. Reith, A critical review on questionnaire surveys in the field of energy-related occupant behaviour, Energ. Effi. 11 (2018) 2157–2177, https://doi.org/10.1007/s12053-018-9711-z.

[80] C. Zhang, F. Conrad, Speeding in web surveys: the tendency to answer very fast and its association with straightlining, Survey Res. Methods 8 (2014) 127–135, https://doi.org/10.18148/srm/2014.v8i2.5453.

[81] Y.-C. Chen, C.-Y. Chen, H.-J. Chen, Integrate gamification into questionnaire design, in: Human-Computer Interaction, Springer, Cham, 2023, pp. 18–29, https://doi.org/10.1007/978-3-031-35596-7_2.

[82] Serious games continuum: Between games for purpose and experiential environments for purpose, Entertainment Computing 2 (2011) 61–68. https://doi.org/10.1016/j.entcom.2010.12.004.

[83] D. Jareemit, B. Limmeechokchai, Impact of homeowner's behaviours on residential energy consumption in Bangkok, Thailand, J. Build. Eng. 21 (2019) 328–335, https://doi.org/10.1016/j.jobe.2018.10.030.

[84] Y. Zhang, X. Bai, F.P. Mills, Characterizing energy-related occupant behavior in residential buildings: evidence from a survey in Beijing China, Energy Build. 214 (2020) 109823, https://doi.org/10.1016/j.enbuild.2020.109823.

[85] M. Pothitou, R.F. Hanna, K.J. Chalvatzis, Environmental knowledge, pro-environmental behaviour and energy savings in households: an empirical study, Appl. Energy 184 (2016) 1217–1229, https://doi.org/10.1016/j.apenergy.2016.06.017.

[86] S. Stancu, A.M. Hristea, C. Kailani, A. Cruceru, D. Bălă, A. Pernici, Exploring influencing factors of energy efficiency and curtailment: approaches to promoting sustainable behavior in residential context, Sustainability 17 (2025) 4641, https://doi.org/10.3390/su17104641.

[87] G. Trotta, Factors affecting energy-saving behaviours and energy efficiency investments in British households, Energy Policy 114 (2018) 529–539, https://doi.org/10.1016/j.enpol.2017.12.042.

[88] X. Chen, Z. Gou, Bridging the knowledge gap between energy-saving intentions and behaviours of young people in residential buildings, J. Build. Eng. 57 (2022) 104932, https://doi.org/10.1016/j.jobe.2022.104932.

[89] M.M. Alomari, H. EL-Kanj, A. Topal, N.I. Alshdaifat, Energy conservation behavior of university occupants in Kuwait: a multigroup analysis, Sustainable Energy Technol. Assess. 52 (2022) 102198, https://doi.org/10.1016/j.seta.2022.102198.

[90] F. Belaïd, H. Joumni, Behavioral attitudes towards energy saving: Empirical evidence from France, Energy Policy 140 (2020) 111406, https://doi.org/10.1016/j.enpol.2020.111406.

[91] L. Niamir, O. Ivanova, T. Filatova, A. Voinov, H. Bressers, Demand-side solutions for climate mitigation: bottom-up drivers of household energy behavior change in the Netherlands and Spain, Energy Res. Soc. Sci. 62 (2020) 101356, https://doi.org/10.1016/j.erss.2019.101356.

[92] C. Bae, J.Y. Lee, D. Kim, C. Chun, Understanding residents' energy consumption Profiles: Behavioral segmentation analysis of heat energy consumption in Korean apartment residences, Energy Build. 319 (2024) 114482, https://doi.org/10.1016/j.enbuild.2024.114482.
[93] X. Ru, S. Wang, S. Yan, Exploring the effects of normative factors and perceived behavioral control on individual's energy-saving intention: an empirical study in eastern China, Resour. Conserv. Recycl. 134 (2018) 91–99, https://doi.org/10.1016/j.resconrec.2018.03.001.
[94] University of Bologna, The university of bologna in figures, University of Bologna (n.d.). https://www.unibo.it/en/university/who-we-are/university-today/the-university-of-bologna-in-figures (accessed August 11, 2025).
[95] Y. Zhang, S. Hu, D. Yan, S. Guo, P. Li, Exploring cooling pattern of low-income households in urban China based on a large-scale questionnaire survey: a case study in Beijing, Energy Build. 236 (2021) 110783, https://doi.org/10.1016/j.enbuild.2021.110783.
[96] A. Tyson, B. Kennedy, C. Funk, Gen Z, Millennials Stand Out for Climate Change Activism, Social Media Engagement With Issue, Pew Research Center (2021). https://www.pewresearch.org/science/2021/05/26/gen-z-millennials-stand-out-for-climate-change-activism-social-media-engagement-with-issue/ (accessed November 8, 2025).
[97] M. van Middelkoop, K. Vringer, H. Visser, Are dutch residents ready for a more stringent policy to enhance the energy performance of their homes? Energy Policy 105 (2017) 269–282, https://doi.org/10.1016/j.enpol.2017.02.050.
[98] T. Hargreaves, M. Nye, J. Burgess, Making energy visible: a qualitative field study of how householders interact with feedback from smart energy monitors, Energy Policy 38 (2010) 6111–6119, https://doi.org/10.1016/j.enpol.2010.05.068.
[99] C. Zhang, K. Qu, Z. Li, Reducing household electricity use through smart meters: the role of improved consumer energy awareness, Energy Build. 347 (2025) 116318, https://doi.org/10.1016/j.enbuild.2025.116318.
[100] W. Abrahamse, L. Steg, C. Vlek, T. Rothengatter, The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents, J. Environ. Psychol. 27 (2007) 265–276, https://doi.org/10.1016/j.jenvp.2007.08.002.
[101] W. Kempton, L.L. Layne, The consumer's energy analysis environment, Energy Policy 22 (1994) 857–866, https://doi.org/10.1016/0301-4215(94)90145-7.
[102] N. Hall, L. Romanach, S. Cook, S. Meikle, Increasing energy-saving actions in low income households to achieve sustainability, Sustainability 5 (2013) 4561–4577, https://doi.org/10.3390/su5114561.
[103] Y. Peng, J. Gaspari, L. Marchi, Exploring residential energy behaviour of the younger generation for sustainable living: a systematic review, Energies 17 (2024) 3043, https://doi.org/10.3390/en17123043.
[104] A. Tantau, S.I. Goia Agoston, V.M. Dincă, C. Păunescu, S. Stamule, T. Stamule, A. Bogdan, Exploring the generation Z attitude towards energy efficiency improvement and decarbonization through heat pumps: An empirical study in romania, Sustainability 16 (2024) 1250, https://doi.org/10.3390/su16031250.
[105] D. Shi, L. Wang, Z. Wang, What affects individual energy conservation behavior: personal habits, external conditions or values? an empirical study based on a survey of college students, Energy Policy 128 (2019) 150–161, https://doi.org/10.1016/j.enpol.2018.12.061.
[106] E. Naghiyev, R. Shipman, M. Goulden, M. Gillott, A. Spence, Cost, context, or convenience? Exploring the social acceptance of demand response in the United Kingdom, Energy Res. Social Sci. 87 (2022) 102469, https://doi.org/10.1016/j.erss.2021.102469.
[107] B. Sütterlin, T.A. Brunner, M. Siegrist, Who puts the most energy into energy conservation? A segmentation of energy consumers based on energy-related behavioral characteristics, Energy Policy 39 (2011) 8137–8152, https://doi.org/10.1016/j.enpol.2011.10.008.
[108] I. Ajzen, The theory of planned behavior, Organ. Behav. Hum. Decis. Process. 50 (1991) 179–211, https://doi.org/10.1016/0749-5978(91)90020-T.
[109] S. Wang, S. Lin, J. Li, Exploring the effects of non-cognitive and emotional factors on household electricity saving behavior, Energy Policy 115 (2018) 171–180, https://doi.org/10.1016/j.enpol.2018.01.012.
[110] R. Yang, C. Yue, J. Li, J. Zhu, H. Chen, J. Wei, The influence of information intervention cognition on college students' energy-saving behavior intentions, Int. J. Environ. Res. Public Health 17 (2020) 1659, https://doi.org/10.3390/ijerph17051659.
[111] S. He, Y. Luo, Y. Qu, X. Hu, Does it work? exploring the influence mechanism of financial incentives in cultivating pro-environmental behavior among college students, J. Clean. Prod. 436 (2024) 140695, https://doi.org/10.1016/j.jclepro.2024.140695.
[112] Z. Guo, K. Zhou, C. Zhang, X. Lu, W. Chen, S. Yang, Residential electricity consumption behavior: influencing factors, related theories and intervention strategies, Renew. Sustain. Energy Rev. 81 (2018) 399–412, https://doi.org/10.1016/j.rser.2017.07.046.
[113] M. Xing, X. Luo, X. Liu, Z. Ma, N. Li, Impacts of building energy consumption information on energy-saving intention of college students, Buildings-Basel 12 (2022) 769, https://doi.org/10.3390/buildings12060769.
[114] E. Park, J.Y. Ohm, Factors influencing the public intention to use renewable energy technologies in South Korea: effects of the fukushima nuclear accident, Energy Policy 65 (2014) 198–211, https://doi.org/10.1016/j.enpol.2013.10.037.