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Research article

Research on the energy saving behaviors of university students based on TPB in a hot summer–cold winter area in China

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A B S T R A C T

Energy saving in higher education institutions holds significant importance in the establishment of environmentally friendly and low-carbon societies, with the energy-saving behaviors of university students playing a pivotal role in the development of sustainable campuses. However, there is a clear need for customized strategies to encourage energy-saving habits among university students in areas of China with extreme weather conditions, such as hot summers and cold winters. This study offers a thorough examination of the literature regarding energy-saving behaviors among college students and presents a new theoretical framework based on the Theory of Planned Behavior (TPB). A survey questionnaire is conducted at universities in regions with hot summers and cold winters across China, with the goal of identifying the main factors that influence students' intentions and actions regarding campus energy conservation. From July to August 2022, we collected 512 survey responses from different university campuses in China's hot summer-cold winter weather zone. The survey asked about subjective norms, understanding of energy conservation, and the importance of saving energy. Utilizing the Structural Equation Model (SEM), we examined how influencing factors are associated with energy conservation behaviors. Our findings indicate that (1) both the significance of energy conservation and subjective norms significantly drive energy-saving actions; (2) distinct factors impact different forms of energy-saving practices; and (3) the inclination to save energy partially mediates the relationship between comfort choices and the significance of energy conservation. This study presents a validated behavioral model tailored for regions experiencing hot summers and cold winters, offering valuable insights for college administrators in managing energy usage while also serving as a theoretical reference for establishing environmentally sustainable campuses.

Abbreviations

ESBs	Energy-saving behaviors	TPB	Theory of Planned Behavior
CP	Comfort preference	KES	Knowledge of energy saving
VES	Value of energy saving	PSE	Perceived self-efficacy
SN	Subjective norms	IES	Intention of energy saving
HESBs	Habitual ESB	CESBs	Constrained ESBs
IESBs	Interpersonal ESBs	SEM	Structural equation model

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1. Introduction

Energy has been a constant companion throughout human history, serving as an indispensable resource for human production and sustenance [1]. The rapid growth of the global population and the progress of society have led to a significant increase in the demand for energy [2]. Although fossil fuel energy has contributes to economic development, it also has raise to serious environmental and health problems [3]. Buildings consume approximately 3060 Mtoe of energy annually, accounting for roughly 36 % of global energy consumption and 28 % of CO_2 emissions related to energy use [4]. China has set ambitious targets to peak its CO_2 emissions by 2030 and achieve carbon neutrality by 2060. China's efforts to reduce carbon emissions are crucial to the sustainable development of the global environment and energy. The country's efforts in reducing carbon emissions are pivotal for the sustainable development of the global environment and energy. According to a report titled "National Education Development Situation in 2021″ by the Ministry of Education in China, there are a total of 3,012 colleges and universities with an enrollment of 44.3 million students in higher education, representing approximately 3.3 % of China's total population—close to that of Spain but surpassing that of Canada. Campus energy consumption in China accounts for approximately 8 % of national energy consumption. Energy usage in educational institutions emerges as a significant aspect of China's end-use energy consumption, which is socially vital and cannot be disregarded. The establishment of a sustainable green campus with high efficiency, wisdom, low-carbon consumption, and humanity has become an urgent and necessary component of campus development [1]. As major energy consumers in colleges and universities, the ESBs (Energy-Saving Behaviors) of university students can reduce building energy consumption on college campuses and contribute to achieve the goal of low-carbon emission for society [5].

Boosting the performance of energy-saving products and optimizing energy utilization, along with advancing energy-efficient technologies, can effectively reduce carbon emissions [6]. However, it is essential to carefully analyze the impact of building occupants or users, namely human influence [7]. Several studies have shown that the diverse behaviors of occupants can result in up to a 20 % variance in energy consumption within buildings [8]; Thus, it is imperative to study the energy-saving actions (ESBs) of contemporary university students [9] in order to expedite China's transition to a low-carbon future and achieve the goal of rapidly peaking carbon emissions. There exists a significant disparity between the energy-saving behavior of contemporary university students and the requirements for constructing a low-carbon society [2], necessitating further research and exploration.

The varied manifestations of ESBs among contemporary college students necessitate meticulous observation and investigation. In recent years, many researchers have conducted studies on the effects of differences in social characteristics on ESBs, such as gender [10], income [11], age [12], level of education [13], and family member structure [14]. In addition, other researchers have explored the factors influencing energy-saving behaviors, including attitudes [15], subjective norms [16], intentions [17], and awareness of consequences [18]. However, only a limited number of studies have delved into the differences in energy-saving behaviors across groups [19], which remain substantial. Some researchers posit that occupants' ESBs are associated with building type, particularly university students residing within campus dormitories. The majority of these students are housed in dormitory buildings with 4–6 students per dormitory unit within an area of 32–72 m^2. The behavior pattern of university students inhabit dormitory buildings with 4–6 individuals per unit spanning an area of 32–72 m^2. The behavioral patterns exhibited by university students on campus are largely homogeneous due to their collective living or classroom environment. While residents primarily engage in independent activities, university students are more susceptible to influence from the communal atmosphere [20]. In a similar manner, the energy-saving behaviors of university students may significantly vary from those of residents [21]. Calderon [22] predicts that 377 million students worldwide will enter university by 2030. Thus, diverse climate regions have an impact on energy consumption and energy-saving practices· However, previous research on university students' ESBs have not addressed the influence of climatic regions they reside in, particularly within the context of China. When considering areas with hot summers and cold winters, Deng and collagues [5] analyzed monthly electricity usage data for appliances in two large university dormitory structures. Alternatively, Ge et al. [23] measured cooling, window opening, and energy consumption for 15 months in a university research building. Wang et al. [24] assessed the energy-saving behaviors of college students in China's region characterized by hot summers and mild winters. Therefore, the objective of this study is to investigate the energy-saving behaviors of college students in regions of China characterized by hot summers and cold winters, specifically focusing on areas near the middle and lower parts of the Yangtze River, including Shanghai, Hubei, Hunan, Chongqing, and Zhejiang [25]. The average temperature in this region ranges from 0 °C to 10 °C during the coldest month and from 25 °C to 35 °C during the hottest month. With a summer period lasting approximately 3–4 months and an average indoor temperature ranging between 30°C and 33 °C with around 80 % humidity, as well as a cold period lasting for about 2–3 months with a mean indoor temperature of only 0°C-6°C in the coldest month. These unique climatic characteristics necessitate both cooling rooms in summer and heating them in winter. In addition, the heating method is not centralized [26]. In this climate region, leading to longer periods of heating and air conditioning throughout the year and subsequently higher building energy consumption [33]. However, there is limited research on the energy-saving habits of college students in hot summer and cold winter areas, as well as the factors influencing their behavior. Therefore, this study aims to explore the energy saving behavior and influencing factors of college students in such climatic zones. The three objectives of this study are to define the influencing factors of ESBs among college students in hot summer and cold winter areas, develop a theoretical model of energy-saving behavior, and uncover the cause and effect relationship of different ESBs.

This study builds a theoretical model based on the theory of planned behavior (TPB) to investigate the determinants of energy-saving behaviors among college students residing in regions of China characterized by extreme temperatures. In this context, ESBs are defined as actions taken to conserve energy within buildings. ESBs can be divided into habitual energy saving behaviors (HESBs), constrained energy saving behaviors (CESBs), and interpersonal energy saving behaviors (IESBs) [24]. HESBs involve reducing excessive energy consumption in daily activities, such as using energy-efficient bulbs and switching off lights when exiting a room, without affecting the quality of life. CESBs entail making lifestyle adjustments to achieve desired energy savings, for example, maintaining air conditioning at no lower than 26 °C during summer months. IESBs promote energy conservation in others through leading by example and identifying non-energy-saving behaviors among peers. This research contributes to reducing campus building's carbon footprint and aligns with China's objective of cutting down carbon dioxide emissions.

The study's contributions can be summarized in three aspects. Firstly, a hypothetical model was established based on the TPB theory, comprehensively considering the characteristics of hot summer and cold winter regions. Secondly, the SEM model was utilized to uncover the direct relationship between energy-saving behavior and influencing factors in universities. Finally, this article proposes focused measures through empirical analysis, which can serve as a reference for energy-saving management strategies in universities and the construction of low-carbon and green university campuses.

The thesis is organized in a systematic way: Part 2 discusses the theory of planned behavior and presents the hypotheses. Part 3 explains the research methods and the process of data collection. Data analysis and its outcomes are highlighted in Part 4. Part 5 explore the results, their significance, and proposes policy guidelines. Finally, Part 6 highlights the academic contributions of the study, draws conclusions, and acknowledges its limitations.

2. Literature review and research hypotheses

2.1. Literature review

Energy saving behavior does not occur in isolation among individuals, and there is extensive research on various factors influencing energy saving behavior. Gender disparities in energy-saving concepts and behaviors have been noted by Du et al. [28], while Schulz et al. [29] and Saleem et al. [30] found that women are more inclined to engage in environmental protection behaviors than men. Additionally, Shrestha et al. [31] summarized global studies indicating that women generally have a positive attitude towards energy conservation compared to men. Additionally, Fan et al. [32] highlighted the fact that women have more motivated emotions and

Table 1
Review of energy saving researches in the literature.

Researcher	The year of publication	Research object	Factor
Levine et al. [46]	2012	Washington University undergraduate students	Demographics (age, gender), knowledge, Attitude, Intention
Lee et al. [47]	2016	University students in Malaysia	Attitude, Subjective Norms, Self-efficacy, Intention
Paço et al. [44]	2017	University students in Portugal	Demographics (age, gender), knowledge, Attitude
Rasool et al. [42]	2019	University students in Karachi, Pakistan	Demographics (age, gender, education, income), Awareness of Consequences, Sense of responsibility, Personal norm, Attitude, Subjective Norms, Perceived behavioral control, Intention
Boca et al. [43]	2019	University students in Baia-Mare, Romania	Environmental education, perception, Attitude, Intention
Hansmann et al. [14]	2020	Swiss University students	Demographics (age, gender), green self-identity, Subjective Norms, Perceived behavioral control, psychological variables, Intention
Janmaimool et al. [45]	2021	University students in Thailand	Environmental concern, Perceived self-efficacy, Self-responsibility, Action knowledge, Perceived benefits
Wang et al. [15]	2021	University students in China	Gender, Grade, Discipline, Comfort preference, Energy conservation value, Knowledge, Perceived self efficacy, Intention
Du et al. [28]	2022	university students in Hong Kong	Attitude, Subjective Norms, Perceived behavioral control, Personal moral norm, Intention
Wang et al. [48]	2022	University students in China	attitude, perceived responsibility, perceived behavior control, subjective norms, energy-saving intention,
Majdi et al. [49]	2022	University students in Kuwait	Attitude, Subjective norms, Perceived behavior control、Environmental Knowledge, Awareness of Consequences
Babatunde et al. [41]	2023	University students in Malaysia	Social norms, Perceived control, Environmental awareness, Energy literacy, Personal attitudes
Liu et al. [50]	2023	University students in China	Attitude, Perceived behavioral control, Subjective norms, Personal norms
Heib Liu et al. [51]	2023	University students in Germany	Personal norm, Energy saving intention, Perceived behavior control, Personal norm
Wang Liu et al. [52]	2024	University students in China	Attitude, Subjective norms, Perceived behavioral control, Personal norms
Duong Liu et al. [53]	2024	University students in Vietnam	Subjective norms, Perceived behavioral control, Scription of responsibility, AAwareness of consequences
Heib Liu et al. [54]	2024	University students in Germany	Descriptive social norm, Injunctive social norm, Personal norm, Perceived behavioral control, Energy saving intention, Attitude

adherence to social norms when dealing with e-waste behavior. Age has been found to be an important factor in energy-saving behavior. Piao et al. [33] found that as people age, people tend to reduce their energy use and adopt an attitude towards using efficient technologies. Furthermore, attitudes [15], subjective norms [34,35], intentions [9,36] and perceived behavioral control [37,38], environmental knowledge [39,40] have all been shown to significantly impact ESBs according to the literature; however, the ordering of effect sizes remains contradictory across studies. The impact of attitudes, subjective norms, intentions, perceived behavioral control and environmental knowledge on energy-saving behaviors (ESBs) has been extensively studied [9,37,40], However, the literature presents contradictory findings regarding the ordering of effect sizes. For example, Babatunde et al. [41] concluded that social norms and perceived behavioral control are the primary important factors influencing energy saving behavior, while Qalati [37] argued that only perceived behavioral control has the most significant impact on energy saving behavior. However, Du et al. [28] confirms that energy-saving behavior is strongly influenced by behavioral intention. In summary, a more comprehensive understanding of energy-saving behaviors and intentions can be achieved through analysis using psychosocial indicators. Moreover, literature [37] has also confirmed the indirect mediating effect of energy-saving intention on attitudes, subjective norms, perceived behavioral control, and energy-saving behavior. From an academic perspective, a number of studies have evaluated the performance of energy-saving behaviors among college students, these studies are summarized in Table 1. Hansmann et al. [14] conducted a study on environmentally beneficial behaviors and the potential influence of students at the Federal Institute of Technology in Lausanne, Switzerland. The researchers discovered that green self-identity merged as a primary predictor in the model. Other predictors, such as willingness to sacrifice, gender, and perceived environmental control, also had significant influence on the model. Rasool et al. [42] examined energy saving among university students in Karachi, Pakistan, and mentioned that subjective norms, attitudes, responsibility, awareness of consequences, and individual standards exhibited a favorable correlation with actions aimed at conserving energy. Similarly, Boca et al. [43] explored the environmental education and ESBs of Romanian university students and identified a positive relationship among perceived, attitudinal, and behavioral variables. Paço and colleagues [44] found no direct link between knowledge and attitudes but observed only a faint connection between attitudes and actions. Meanwhile Janmaimool et al. [45] undertook research at King Mongkut's University of Technology Thonburi in Bangkok, where they found that perceived advantages of energy-saving actions, worries about global warming were more effective in encouraging ESBs in college students than other factors like self-efficacy.

2.2. Research hypotheses

The Theory of planned behavior (TPB) is a well-developed theoretical framework, originating from the theory of justified action proposed theoretical framework, originating from the theory of justified action proposed by Ajzen [34]. Building upon the theory of reasoned action, behavioral intention directly influences behavior and is shaped by perceptions about the behavior and related subjective norms. While the theory of reasoned action posits that volition governs individual behavior, Fishbein et al. [56] proposed that behavioral attitude plays a primary role in influencing behavioral intention. They also underscored the importance of subjective

Table 2
Description and representation of the variables.

Variable Name	Unit	Description and representation of the variables
Dependent Variables		
Energy Saving Behaviors	Impact factor	Energy saving behaviour is controlled by energy saving intentions to reduce energy consumption. In this study, the main categories are habitual energy saving behaviors, constrained energy saving behaviors and interpersonal energy saving behaviors. Path analyses were conducted using a Likert scale with structural equation modelling for this latent variable. Same for the following unit-consistent variablestors for each pathway was made.
Mediating variables		
Intention of Energy Saving	Impact factor	Intention of Energy Saving to save energy refers to people's drive to save energy that is transformed by the influence of external factors.
Independent Variables		
Gender	Binary	Gender of university students interviewed.(Male or Female)
Grade	Multiple-choice	Grade level of university students interviewed.(Freshman Sophomore、Junior、Senior or Postgraduate)
Discipline	Multiple-choice	Disciplines studied by university students interviewed.(Art、Economy、Education、Engineering、History、Law、Literature、Management or Medical Science)
Comfort Preference	Impact factor	Comfort preference is the internal psychological pursuit of people to satisfy their comfort needs through energy consumption behavior.
Value of Energy Saving	Impact factor	The energy-saving values that people respond to when they form energy-saving behavioural intentions and engage in corresponding energy-saving behaviours
Subjective Norms	Impact factor	Subjective norms reflect the social pressures that individuals feel when deciding whether or not to engage in a particular behaviour. In this study, the social pressure on students to save energy mainly comes from social morality, the energy-saving system of the university, and the atmosphere created by the people around them in their lives and studies.
Knowledge of Energy Saving	Impact factor	Knowledge of energy saving, as reflected in this study, is the value of energy efficiency that is reflected in the process of driving the formation of energy efficiency behaviours after people have formed an intention to do so, and the perceived advantages that come from the implementation of energy efficiency behaviours
Perceived Self-efficacy	Impact factor	Perceived self-efficacy in this study refers to college students' perceptions and implementation of daily energy-saving behaviours and their influence on the energy-saving behaviours of others

norms and perceived control over behavior as key factors. In contrast, the five elements of the TPB are general, and the theory enables significant extensions and modifications to meet practical needs [37]. Conversely, many researchers have adopted TPB as a foundational framework for studying energy conservation behaviors. For instance, Qalati et al. [37] demonstrated how household willingness and moral responsibility to save energy play an important mediating and moderating role in household energy saving intentions and behaviour. Yang et al. [21] explored how perceived information intervention influences college students' readiness to embrace energy-saving behaviors. Wang et al. [25] explore the factors that influence HESBs by distinguishing between altruism and selfishness. Furthermore, in their research, Liu et al. [26] engage in an in-depth examination of energy-conservation practices within domestic settings. Conversely, Xu et al. [27] scrutinize the determinants that impact individual energy-saving conduct. Finally, Wang et al. [15] stress the impact of individual characteristics on the adoption of energy-conservation practices within domestic settings. Thus, the research current extends the TPB with a model of energy saving behaviors. Table 2 shows the individual variables, measurement units and descriptions used in the hypothetical TPB model.

Comfort preference is the intrinsic psychological pursuit of people to enable themselves to satisfy their comfort needs through energy consumption behavior. Sintov et al. [57] argued that comfort significantly influences the energy-saving behaviors (ESBs) of household members. Rouleau et al. [58] also cited that comfort exerts an impact on the ESBs of occupants in buildings. In addition, Xu et al. [59] mentioned that workers with a firm conviction in energy-saving are ready to forgo some level of comfort to conserve energy. This study presents the following subsequent assumptions:

H1. Desire for comfort contributes positively to the intention to save energy.

Energy efficiency is a reflection of the outcomes of ESBs and is broadly defined as the values associated with energy conservation. Nguyen et al. [60] suggest that individuals who hold sustainable or eco-friendly beliefs often perceive themselves as environmentally responsible, aligning their actions with their principles. Furthermore, Abrahamse et al. [61] conclude that there exists a significant connection between self-transcendent values (e.g., tradition/security and power/achievement) and household energy consumption. Additionally, there is a positive association between the intention to decrease household energy use and the importance placed on energy conservation. Chan [62] notes that in societies with pronounced cultural and socio-ecological limits, the link between self-transcendent values and pro-environmental actions promoting self-enhancement was tenuous. (e.g., low levels of self-expressive values and economic development). Respondents demonstrating higher levels of altruism and a strong focus on the biosphere exhibit greater commitment to taking action for the benefit of the environment. Furthermore, De Groot et al. [63] discovered that individuals who prioritize egoistic values tend to display less self-determined environmental behavior. The presence of strong self-determined motivation is also crucial in explaining intention when altruism, particularly with regard to biosphere values, serves as a significant predictor of pro-environmental intention. In essence, it can be concluded that different values lead to varying levels of environmentally sustainable behaviors (ESBs). As such, this study puts forth an additional hypothesis:

H2. The value of energy saving exerts a positive effect on the intention to save energy.

Subjective norms pertain to the societal influence and pressure perceived by individuals to conform to a specific behavior. The social pressure on university students to save energy is mainly derived from energy saving norms in school facilities, ESBs of peers, and their knowledge of energy conservation. According to Dolan et al. [64] subjective norms are believed to impact the intention of saving energy. Dixon et al. [65] have a significant influence on ESBs. Furthermore, Chen et al.[66 [][][]explore the energy-saving intention of low-income households in the United States and obtain the conclusion that the influence of subjective norms was beneficial for promoting the inclination to conserve energy. Therefore, this study hypothesizes that:

H3. The intention to save energy is positively influenced by subjective norms.

The comprehension of energy-saving knowledge by individuals pertains to the objective principles of energy conservation as applied in both professional and personal contexts. Chen et al. [67] indicate that domestic users of university building lack knowledge about building energy efficiency and that the majority of building users are unable to fully understand or even partially understand feedback on the energy-saving design and operation of their buildings, which, thus, fails to provide reasonable guidance on their energy-using behavior. Dursun et al. [68] have categorized knowledge about energy saving into subjective and objective forms, demonstrating that objective environmental knowledge can help identify psychological barriers to energy-saving behaviors. However, Kaplowitz et al. [69] have found that despite possessing extensive knowledge about energy conservation, laboratory management and personnel do not necessarily exhibit a positive intention to conserve energy. To sum up, understanding energy conservation typically boosts the motivation to save energy. Therefore, the study proposes the following hypothesis:

H4. Knowledge of energy saving exerts a positive impact on the intention of energy saving.

Self-efficacy is the assumption and judgment of individuals about their behavioral capacity. In this regard, Bandura [70] suggested that the abilities and skills required vary widely across activity areas. Lee et al. [47] have investigated how self-efficacy positively influenced intentions related to energy conservation. Therefore, the research hypothesis is as follows:

H5. Perceived self-efficacy has a positive impact on the intention to save energy.

In relation to the TPB, Ajzen [55] suggests that when control variables related to perception of behavior are taken into account, there is a strong intention to save energy, particularly under partial willpower control. Energy-saving intention represents an individual's preparedness to adopt a specific behavior, reflecting their perceived likelihood of embracing that particular action. The TPB model [55] proposes that Behavioral intent has a notable positive impact on behavior and that factors, for instance, subjective norms, perceptual behavior control and attitude, indirectly influence behavior mainly through behavioral intention. In their study, Rizzi et al. [71] delve into the determinants affecting consumers' willingness findings confirm the impact of energy-saving intention on ESBs.

Therefore, the current study presents the assumptions:

H6. Intention of energy saving exerts a positive impact on (a) HESBs, (b) CESBs, and (c) IESBs.

Building on the aforementioned considerations regarding the influence of energy-saving intention and behavioral intention on behavior, the study has constructed a simplified model based on the energy-saving behaviors of university students [24]. This model is grounded in previous research [24] and is depicted in Fig. 1, representing the conceptual framework that will be examined in this paper.

3. Research methods

This study was conducted among college students in in regions of China experiencing hot summers and cold winters. Firstly, TPB was designated as the theoretical energy-saving behavior model to demonstrate the decision-making process of daily energy-saving behavior among college students. Then, corresponding measures were selected to evaluate each variable in the model. Subsequently, appropriate measures were selected to assess each variable within the model. An extensive online survey questionnaire was then designed and administered to the target population in order to gather information and descriptive characteristics of the sample, followed by data analysis including testing for direct and indirect effects as well as diversity analysis. Reliability analysis and structural equation modeling (SEM) were utilized in this study, enabling conclusions to be drawn regarding reliability, validity, bias within the general methodology, and factors influencing energy-saving behavior.

3.1. Data collection

For data collection, the study chose to employ the questionnaire previously developed by Wang and colleagues [24] in order to create a formal questionnaire (the completed questionnaire can be accessed at the website: https://www.wjx.cn/vm/YDTrYbS.aspx#). The author sets a limitation in the survey, and respondents could only submit a single response, so that each respondent represents himself. That way, this can avoid sampling bias. The questionnaire had two principal sections. The first section captured participants' demographic details like gender, study field, and academic year. The second section zeroed in on determinants affecting students' energy-saving habits, gauging aspects like comfort preference, subjective norms, energy-saving value and awareness, conservation intention, and perceived self-efficacy. For each indicator in the questionnaire weighting, the respondents were given the following options: 1 = *strongly disagree*, 2 = *disagree*, 3 = *agree*, and 4 = *strongly agree*.

This questionnaire was distributed to university students in Hangzhou, Jiaxing, Nanchang, Shanghai, and Wuhan, which are typical cities with hot summers and cold winters. These cities have similar climate characteristics, and the university students participating in the survey have similar behavior patterns, which all help to ensure the validity, scientificalness and availability of the questionnaire. The questionnaire period for this paper was from July to August 2022, which lasted approximately 2 months, and 512 valid questionnaires were returned. The sample size adheres to the n/q guideline mandated by SEM, with n representing the case count and q denoting the parameters awaiting estimation. Hair et al. [52] suggests that the ratio value is 10, while Kline et al. [73] suggests that the ratio value is between 5 and 20. The final questionnaire validated the theoretical framework and addresses issues related to the field of energy-saving behaviours among university students. All data were obtained from the popular Chinese professional survey website Wenjuanxing (https://www.wjx.cn).

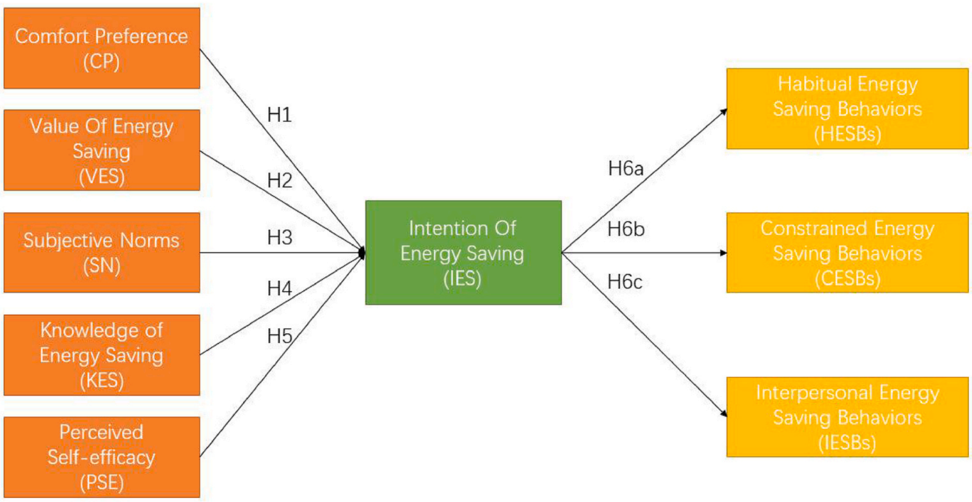

Fig. 1. Research theoretical framework for energy-saving behaviours.

3.2. Data analyses

Data analyses included descriptive, reliability, and valid factor analyses and assessment of both the immediate and mediated effects. The stability of the sample data will directly influence the stability of the analysis results; thus, the study tested the stability of the scales using Cronbach's alpha coefficient based on the mean correlation between items using SPSS Statistics 25 software.

The study employed latent variable models to investigate the connections among various variables including regression analysis, multiple correlation analysis, factor analysis, and pass-through analyses (multiple regression analysis) [72,74]. SEM is an increasingly popular latent variable model for investigating the relationships between environmental behaviors and influencing factors [21,75–78]. Alternatively, Mplus software can availably integrate mathematical statistics with practical questionnaire research and greatly accelerate the application of latent variable modeling and analysis, which surpasses other modeling software such as Amos and Lisrel. Therefore, this study used the modeling software Mplus for variable reliability and validation factor analyses while testing for general method bias to ensure the availability of the SEM model and enhance its structural suitability. Finally, direct path coefficients were calculated and causal relationships were analyzed.

The nonparametric percentile bootstrap method currently used is more exact and robust than the Sobel test and the causal step method [79,80], which was used in the study to verify the mediation analysis of latent variables.

Wen et al.'s research [81] delves into the intricate dynamics of variable relationships. They reveal that when an independent variable significantly influences an intermediate variable (a) (a) and subsequent significant impact of (a) on the dependent variable (b) suggests a potential mediating effect between the independent and dependent variables ($a \times b$). An important consideration arises when either the independent or dependent variable lacks statistical significance. In such cases, it becomes crucial to examine the 95 % Bootstrap confidence interval of ($a \times b$). If this interval excludes 0 and the direct effect (c') is also insignificant, it implies a full mediating effect. This research offers valuable insights into complex statistical relationships, aiding researchers in understanding these nuanced pathways of influence. These findings offer insights into the interplay between independent and dependent variables. Meanwhile, the direct effect(c') was significant when the mediating effect was partial. Besides, the insignificant mediating effect may be caused when the 95 % Bootstrap confidence interval of ($a \times b$) includes 0 when at least (a) or (b) is not significant.

4. Results and analyses

4.1. Respondent profile

Table 3 presents the basic characteristics of the respondents, demonstrating a reasonable gender ratio and no significant disparity in ratios among different grade groups. These findings serve to mitigate the influence of gender and class factors on the data, thereby ensuring the objectivity of the questionnaire survey. Additionally, the distribution of academic subjects aligns closely with the distribution of high school examinees in 2022.

4.2. Outliers analysis

During the data collation and inventory process, outliers in the collected counts were discriminated and cleaned using Z-scores, where Z-scores exceeding ± 3 were excluded from the dataset(Table 4). In addition, incompletely completed questionnaires were excluded from the dataset. Overall, out of 520 questionnaires, 512 questionnaires were included in this study, and the response rate was 98.46 %.

Table 3
Participants' demographics.

Data Class		Quantity	Proportion(%)
Gender	Male	246	48.0
	Female	266	52.0
Grade	Freshman	129	25.2
	Sophomore	183	35.7
	Junior	127	24.8
	Senior	65	12.7
	Postgraduate	8	1.6
Discipline	Art	16	3.1
	Economy	53	10.4
	Education	34	6.6
	Engineering	158	30.9
	History	16	3.1
	Law	20	3.9
	Literature	26	5.1
	Management	77	15.0
	Medical	45	8.8
	Science	67	13.1

Table 4
Sample data outliers analysis table.

Main Constructs	Items	N	Max	Min	Mean	1	2	3	4	5	Standard Deviation	Z_{MAX}
Comfort preference (CP)	CP1	512	1	5	3.44	7.03 %	16.80 %	18.36 %	41.02 %	16.80 %	1.159	−2.103
	CP2	512	1	5	3.51	6.05 %	15.82 %	16.02 %	45.51 %	16.60 %	1.124	−2.230
	CP3	512	1	5	3.49	6.45 %	15.04 %	18.55 %	43.16 %	16.80 %	1.130	−2.203
Value of energy saving (VES)	VES1	512	1	5	3.90	2.34 %	8.01 %	15.82 %	45.31 %	28.52 %	0.983	−2.947
	VES2	512	1	5	3.70	2.93 %	8.79 %	21.29 %	49.22 %	17.77 %	0.958	−2.819
	VES3	512	1	5	3.79	1.76 %	9.77 %	17.58 %	50.00 %	20.90 %	0.943	−2.954
	VES4	512	1	5	3.72	2.34 %	11.52 %	18.75 %	46.68 %	20.70 %	0.995	−2.734
	VES5	512	1	5	3.83	2.73 %	7.03 %	18.75 %	47.85 %	23.63 %	0.961	−2.942
Subjective norms (SN)	SN1	512	1	5	3.59	3.71 %	12.89 %	22.85 %	41.41 %	19.14 %	1.052	−2.466
	SN2	512	1	5	3.38	8.59 %	13.87 %	24.61 %	36.33 %	16.60 %	1.168	−2.042
	SN3	512	1	5	3.50	3.13 %	14.65 %	24.61 %	44.14 %	13.48 %	1.001	−2.500
Knowledge of energy saving (KES)	KES1	512	1	5	2.96	6.45 %	31.05 %	28.91 %	26.95 %	6.64 %	1.051	1.939
	KES2	512	1	5	3.16	5.86 %	25.59 %	26.76 %	30.47 %	11.33 %	1.107	−1.950
	KES3	512	1	5	3.26	5.47 %	22.66 %	26.37 %	31.84 %	13.67 %	1.117	−2.020
	KES4	512	1	5	3.31	5.66 %	19.53 %	26.17 %	34.96 %	13.67 %	1.105	−2.094
Perceived self-efficacy (PSE)	PSE1	512	1	5	3.39	5.08 %	19.73 %	21.88 %	37.30 %	16.02 %	1.123	−2.132
	PSE2	512	1	5	3.34	3.91 %	22.66 %	25.00 %	32.81 %	15.63 %	1.107	−2.110
	PSE3	512	1	5	3.38	2.54 %	21.29 %	27.93 %	32.62 %	15.63 %	1.062	−2.237
	PSE4	512	1	5	3.45	3.32 %	21.09 %	20.31 %	38.09 %	17.19 %	1.102	−2.221
Intention of energy saving (IES)	IES1	512	1	5	3.71	4.10 %	11.72 %	19.14 %	39.45 %	25.59 %	1.096	−2.469
	IES2	512	1	5	3.71	3.91 %	9.96 %	22.66 %	38.67 %	24.80 %	1.068	−2.534
	IES3	512	1	5	3.63	3.13 %	15.63 %	20.31 %	37.11 %	23.83 %	1.101	−2.388
	IES4	512	1	5	3.72	3.52 %	12.70 %	19.34 %	37.50 %	26.95 %	1.100	−2.471
	IES5	512	1	5	3.72	3.91 %	12.11 %	17.97 %	40.04 %	25.98 %	1.095	−2.484
Habitual ESB (HESBs)	HESBs1	512	1	5	3.84	4.69 %	13.09 %	15.82 %	26.17 %	40.23 %	1.218	−2.333
	HESBs2	512	1	5	3.68	4.30 %	11.13 %	25.59 %	30.08 %	28.91 %	1.131	−2.372
	HESBs3	512	1	5	4.01	2.93 %	8.01 %	16.41 %	30.27 %	42.38 %	1.131	−2.780
Constrained ESBs (CESBs)	CESBs1	512	1	5	3.44	8.01 %	13.87 %	26.76 %	29.10 %	22.27 %	1.205	−2.023
	CESBs2	512	1	5	3.52	5.27 %	12.70 %	27.73 %	33.20 %	21.09 %	1.115	−2.261
	CESBs3	512	1	5	3.40	8.59 %	14.84 %	25.59 %	30.08 %	20.90 %	1.214	−1.976
Interpersonal ESBs (IESBs)	IESBs1	512	1	5	3.24	9.96 %	17.77 %	27.73 %	26.95 %	17.58 %	1.222	−1.837
	IESBs2	512	1	5	3.39	5.86 %	15.04 %	30.66 %	30.86 %	17.58 %	1.116	−2.144
	IESBs3	512	1	5	3.27	10.16 %	16.21 %	28.13 %	27.93 %	17.58 %	1.218	−1.860

4.3. Dependability, availability, and common methodological biases

To assess the reliability of the measurement model, a variety of criteria were utilized, including Cronbach's alpha coefficients and composite reliability. Convergent validity was evaluated using the average variance extraction approach, while discriminant validity was assessed through both the Fornell–Larcker criterion and the heterotrait–monotrait (HTMT) ratio. The details regarding convergent validity, discriminant validity, and indicator reliability are provided in Table 5 of the study. It is evident from Table 5 that the Cronbach's alpha coefficient values for each latent variable of the model are >0.73, which indicate that the scale's reliability falls within the acceptable boundaries. Additionally, the overall Cronbach's alpha coefficient for all variables stood at 0.896, surpassing the suggested 0.6 threshold proposed by Robinson et al. [82] These findings demonstrate commendable overall reliability of the scale. The maximum likelihood estimation (MLE) method is widely used for parameter estimation method in confirmatory factor analysis [83], The results of the validated factor analysis, which involved a model with 9 factors and 32 items using MLE, demonstrated that the majority of the measured variables produced standardized factor loadings >0.6. Several measured variables with standardized factor loadings >0.45 (0.551) were also acceptable [84]. The component reliability exceeded the threshold of 0.70 [85], further attesting to its strong internal consistency. Convergent validity was assessed using average variance extracted for each structure, all of which yielded AVE values > 0.36, indicating acceptable convergent validity [86,87].

The validity of the study was assessed using the Fornell–Larcker criterion and HTMT ratio. According to the Fornell–Larcker criterion, discriminant validity can be measured using the square root of the AVE (i.e., diagonal values) and should be higher than the highest correlation with other structures (non-diagonal values). Results are presented in Table 6, indicated that the lowest square root value for the nine factors (0.665) surpasses the highest inter-factor correlation coefficient, which stands at 0.523 [74,88,89]. Additionally, we employed the HTMT ratio as another criterion to address potential insensitivity issues introduced by the Fornell–Larcker criterion [90]. Henseler et al. [89] proposed that the HTMT ratio is a more robust and superior method. According to Kline [74], the threshold for HTMT must be < 0.85. The results obtained in this study show that all HTMT values were lower than the conservative threshold of 0.85 (as shown in Table 7). This suggests strong discriminant validity among the factors.

To control or reduce common method variance [91] or common method bias [92], scholars typically adopted program and statistical controls [92,93]. Our study used Harman's simple test for the presence of common method bias in the data [94]. Common method bias were tested for all scale items using the one-way validated Harman's factor analysis. The results demonstrated a good model fit: NORM CHI-SQR = 1.252, RMSEA = 0.022, SRMR = 0.036, GFI = 0.932, AGFI = 0.917 and TLI = 0.983. Therefore, the methods and procedures mentioned above signal a lack of substantial common method bias.

Table 5
Dependability and availability measure of correlations, reliability coefficients, and average variance extracted (AVE).

Main Constructs	Items	Loadings	Cronbach's Alpha	Average variance extracted	Combined reliability
Comfort preference (CP)	CP1	0.803	0.884	0.719	0.885
	CP2	0.901			
	CP3	0.837			
Value of energy saving (VES)	VES1	0.723	0.811	0.466	0.813
	VES2	0.613			
	VES3	0.616			
	VES4	0.725			
	VES5	0.725			
Subjective norms (SN)	SN1	0.676	0.737	0.486	0.739
	SN2	0.717			
	SN3	0.698			
Knowledge of energy saving (KES)	KES1	0.617	0.757	0.442	0.759
	KES2	0.693			
	KES3	0.739			
	KES4	0.601			
Perceived self-efficacy (PSE)	PSE1	0.764	0.890	0.673	0.891
	PSE2	0.763			
	PSE3	0.792			
	PSE4	0.949			
Intention of energy saving (IES)	IES1	0.755	0.862	0.558	0.863
	IES2	0.744			
	IES3	0.679			
	IES4	0.754			
	IES5	0.798			
Habitual ESB (HESBs)	HESBs1	0.832	0.754	0.528	0.766
	HESBs2	0.551			
	HESBs3	0.767			
Constrained ESBs (CESBs)	CESBs1	0.774	0.864	0.699	0.872
	CESBs2	0.999			
	CESBs3	0.706			
Interpersonal ESBs (IESBs)	IESBs1	0.642	0.808	0.622	0.826
	IESBs2	0.997			
	IESBs3	0.678			

Table 6
Measurement of the overall discriminant validity.

Latent variable	CP	VES	SN	KES	PSE	IES	HESBs	CESBs	IESBs
CP	0.848								
VES	0.373**	0.683							
SN	0.165**	0.421**	0.697						
KES	0.079	0.094*	0.127**	0.665					
PSE	0.083	0.338**	0.557**	0.119**	0.820				
IES	0.377**	0.523**	0.305**	0.086	0.193**	0.747			
HESBs	0.390**	0.505**	0.233**	0.000	0.172**	0.459**	0.727		
CESBs	0.111*	0.291**	0.354**	−0.002	0.232**	0.221**	0.348**	0.836	
IESBs	0.091*	0.274**	0.408**	0.115**	0.352**	0.213**	0.169**	0.280**	0.789

Note: ** indicates P < 0.01, * indicates P < 0.05. Diagonal values show the square root of the AVE, whereas off-diagonal values depict Pearson correlations.

Table 7
Ratio between different-trait and same-trait measurements.

Latent variable	CP	VES	SN	KES	PSE	IES	HESBs	CESBs	IESBs
CP	–								
VES	0.351	–							
SN	0.050	0.434	–						
KES	0.134	0.243	0.371	–					
PSE	0.001	0.326	0.680	0.279	–				
IES	0.231	0.447	0.171	0.146	0.198	–			
HESBs	0.335	0.546	0.111	0.021	0.024	0.279	–		
CESBs	0.063	0.261	0.447	0.042	0.19	0.108	0.356	–	
IESBs	0.068	0.419	0.770	0.275	0.546	0.357	0.257	0.315	–

4.4. Structural equation modeling

Various fit indices are used to assess how well structural equation models (SEMs) match up with real-world data, with the chi-squared test being the most commonly used. Table 8 shows the SEM fit indices. Previous research suggests that the chi-squared to degrees of freedom ratio (CHI-SQR/DF) typically falls between 1 and 3 [24]. The Coefficient of Fit Index (CFI) values usually range from 0 to 1, with a threshold of ≥0.9 considered acceptable. However, some researchers argue for CFI values above 0.95 [95], Bentler suggested TLI >0.90 [96], and Henseler recommended that RMSEA and SRMR should be < 0.08 [89]. The model was considered to fit well within the abovementioned ranges. Based on the chi-squared values in Table 8, it can be concluded that the model fits within recommended parameters adequately.

The standardized model fit and structural coefficients are shown in Table 9, the value of energy saving and SN exert a positive influence on constrained ESBs in which SN (0.400) ranks first in terms of importance followed by VES (0.277). The influence of SN and PSE in interpersonal relationships is significant, and that of SN (0.349) on energy-saving behavior is greater than PSE (0.143). Both comfort preference and value of energy saving had a positive influence on IES, and VES (0.489) was greater than CP (0.184). Furthermore, the positive effect of IES on HESBs is particularly significant, with a pathway effect value of 0.255. Nevertheless, our study found that the rest of the paths are non-significant. Therefore, the study concluded that H1, H2, and H6a are encouraged, whereas H3, H4, H5, H6b, and H6c are refused.

4.5. Mediating effects

Mediation effect analysis is a crucial statistical approach in multivariate research, elucidating the impact of independent variables on dependent variables through mediator variables [97]. Tests for the mediator effect were categorized into coefficient difference and

Table 8
Revised structural equation model fit indices.

Fit index	Standards	Study framework	Fit assessment
CHI-SQR	Smaller is better.	574.645	–
DF	Larger is better	459	–
CHI-SQR/DF	3>NORM CHI-SQR>1	1.252	Ideal
P-VALUE	<0.05	0.0002	Ideal
CFI	>0.90	0.985	Ideal
TLI	>0.90	0.983	Ideal
RMSEA	<0.08	0.022	Ideal
SRMR	<0.08	0.036	Ideal

Table 9
Coefficient estimates of model parameters.

Regression relationships	approximation	S.E.	Est./S.E.	P
CP→HESBs	0.196	0.050	3.934	0.000
VES→HESBs	0.450	0.071	6.328	0.000
SN→HESBs	−0.087	0.084	−1.039	0.299
KES→HESBs	−0.095	0.046	−2.038	0.042
PSE→HESBs	−0.013	0.068	−0.190	0.850
CP→CESBs	−0.025	0.051	−0.492	0.623
VES→CESBs	0.227	0.074	3.044	0.002
SN→CESBs	0.400	0.085	4.679	0.000
KES→CESBs	−0.067	0.048	−1.410	0.161
PSE→CESBs	−0.087	0.070	−1.241	0.215
CP→IESBs	−0.039	0.049	−0.782	0.434
VES→IESBs	0.060	0.072	0.830	0.406
SN→IESBs	0.349	0.083	4.222	0.000
KES→IESBs	0.051	0.046	1.115	0.265
PSE→IESBs	0.143	0.067	2.138	0.033
CP→IES	0.184	0.049	3.799	0.000
VES→IES	0.489	0.059	8.497	0.000
SN→IES	0.132	0.082	1.599	0.110
KES→IES	0.024	0.046	0.511	0.609
PSE→IES	−0.071	0.067	−1.064	0.287
IES→HESBs	0.255	0.061	4.159	0.000
IES→CESBs	−0.028	0.064	−0.434	0.664
IES→IESBs	0.045	0.061	0.738	0.461

product examinations [97]. However, due to its high original dummy error rate, the study omitted the coefficient difference test [98]. The coefficient product test includes the Sobel test, asymmetric confidence interval test, bootstrap method, and the Bayesian approach. The Sobel test assumed that the mediating effects were distributed using a standard normal distribution, and the confidence intervals obtained were often large, resulting in the Sobel test being statistically inefficient [99]. Meanwhile, the Bayesian approach relied on the selection of appropriate prior distributions for the model parameters [100], and the asymmetric confidence interval test proposed by Keenan et al. used the critical values of confidence limits to obtain approximate results, which were frequently less precise [101]. Thus, the majority of researchers acknowledged that using the bootstrap method for mediation analysis was a better approach [102, 103].

Following the mentioned notion, the current study uses the bootstrap method in Mplus software. (self-sampling 2000 times) to analyze the mediating effects. In this case, If the coefficient c 'is not significant, then the mediating effect is considered complete; however, if the regression coefficient c' is significant, but $c' < c$, then it is considered that the mediation effect is partial. Bootstrap test outcomes are detailed in Table 10. The table indicates that in the paths "CP→ IES → HESBs" and "VES → IES → HESBs," Our analysis reveals significant relationships: the independent variable impacts (a) significantly, (a) influences (b) significantly, and the direct effect (c') is also significant. Bootstrap sampling confirms these findings with 95 % confidence intervals consistently excluding zero. Therefore, power saving intention is partially mediated by two paths, namely, "CP→ IES → HESBs" and "VES → IES→ HESBs."

In other words, energy-saving behaviors (ESBs) are not solely shaped by the direct impacts of CP and VES but are also influenced by the mediating effects of IES. It is also influenced by the mediating effect of IES, that is, CP and VES partially act on HESBs through IES. The comprehensive effect of factors that influence HESBs (c) is ranked as "VES > CP." Fig. 2 illustrates the model for testing the partial

Table 10
Results of bootstrap test.

Items	c (Total effect)	a	b	a × b (Mediation effect)	a × b (95 % Bootstrap confidence interval)	c' (Immediate impact)	Summary of findings
CP→IES→HESBs	0.243	0.184	0.255	0.047	0.025–0.091	0.196	Partial mediation
VES→IES→HESBs	0.575	0.489	0.255	0.125	0.103–0.281	0.45	Partial mediation
SN→IES→HESBs	−0.053	0.132	0.255	0.034	−0.002~0.126	−0.087	Insignificant
KES→IES→HESBs	−0.089	0.024	0.255	0.006	−0.023~0.045	−0.095	Insignificant
PSE→IES→HESBs	−0.031	−0.071	0.255	−0.018	−0.069~0.011	−0.013	Insignificant
CP→IES→CESBs	−0.030	0.184	−0.028	−0.005	−0.030~0.014	−0.025	Insignificant
VES→IES→CESBs	0.213	0.489	−0.028	−0.014	−0.090~0.062	0.227	Insignificant
SN→IES→CESBs	0.396	0.132	−0.028	−0.004	−0.044~0.011	0.4	Insignificant
KES→IES→CESBs	−0.068	0.024	−0.028	−0.001	−0.016~-0.005	−0.067	Insignificant
PSE→IES→CESBs	−0.085	−0.071	−0.028	0.002	−0.006~0.025	−0.087	Insignificant
CP→IES→IESBs	−0.031	0.184	0.045	0.008	−0.009~0.028	−0.039	Insignificant
VES→IES→IESBs	0.082	0.489	0.045	0.022	−0.039~0.093	0.06	Insignificant
SN→IES→IESBs	0.355	0.132	0.045	0.006	−0.006~0.040	0.349	Insignificant
KES→IES→IESBs	0.052	0.024	0.045	0.001	−0.003~0.017	0.051	Insignificant
PSE→IES→IESBs	0.140	−0.071	0.045	−0.003	−0.023~0.003	0.143	Insignificant

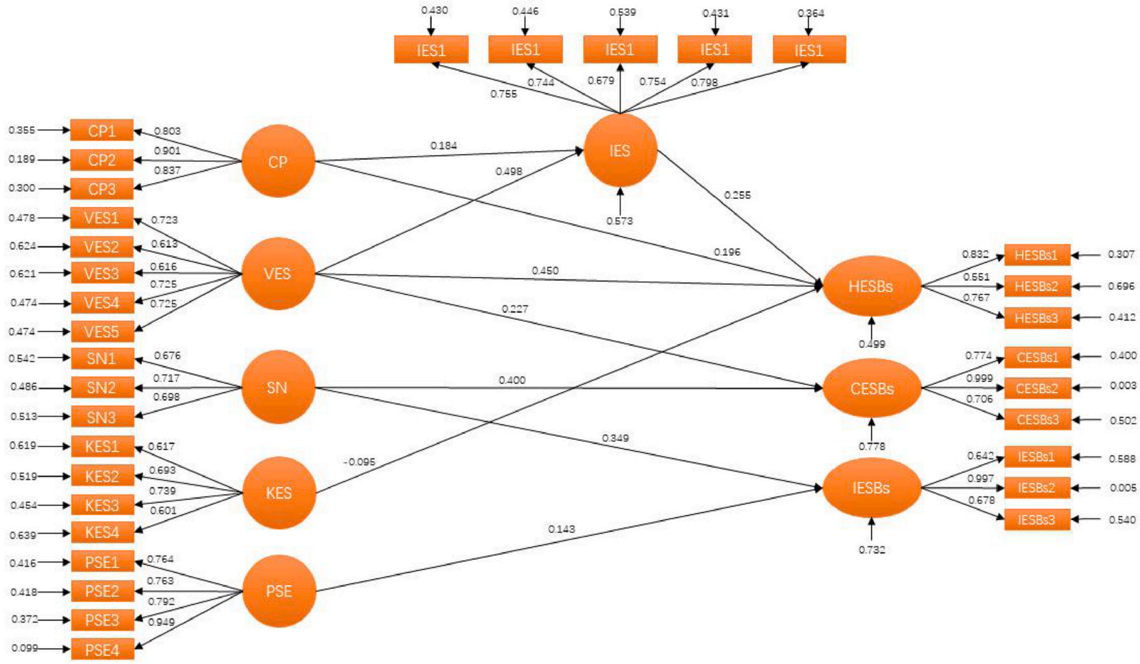

Fig. 2. The mediation effect test model.

mediation effect.

4.6. Diagnostic test

Based on the data in Table 11 below, it was determined that there is no evidence of normality and homoscedasticity as the null hypothesis was rejected for all p-values. Therefore, it can be concluded that there is no issue of heteroskedasticity in the variables and that all variables adhere to a normal distribution. Additionally, the model demonstrates both normality and absence of heteroskedasticity.

5. Discussion and policy implications

5.1. Discussion on energy-saving behavior of college students in hot summer and cold winter areas

This study examines the factors that impact the perceived environmental stressors by college students in regions of China characterized by hot summers and cold winters. The findings are subsequently discussed in relation to prior research and the current situation.

5.1.1. Values

Values are key variables that influence human psychology, attitudes, and behaviors. Li et al. [104] identified a notable positive link between students' values and actions. ESBs influenced by energy-saving values can aid in sustaining the ESBs [105]. Zhang et al. found that personal values and knowledge about energy play a pivotal role in determining household energy-conservation actions, highlighting the significance of individual convictions and understanding in advancing sustainable habits. Additionally, research has indicated that the impact of energy-saving values remains consistent across various regions such as Asia, Europe, and the United States [106]. This underscores the pivotal role of values in deciding the adoption of enduring energy-saving practices. Furthermore, fostering a value for energy conservation can enhance university students' awareness of positive energy-saving practices and lead them to incorporate these practices into their daily lives while cultivating enduring habits related to saving energy.

Table 11
The results of diagnostic tests.

Diagnostic tests	Statistical Value	P-value
Jarque-Bera test	301.345	0.6784
White test	1.742	0.1623
Breusch-Pagan-Godfrey test	1.7646	0.1574

5.1.2. Comfort preference

In addition, comfort preference positively influenced HESBs; the majority of the students believed that the living environment was as important as saving energy and comfortable learning, but they were inclined to sacrifice comfort for the sake of energy conservation and foster beneficial energy-saving routines. The results indicated that the students will acquire positive energy-saving habits if they value energy savinghighly, enabling them to make sacrifices in exchange for a comfortable environment to pursue the value of energy saving.

5.1.3. Knowledge of energy saving

HESBs were evident in terms of adapting work and life performance to sustainable development. Moreover, knowledge of energy saving influenced HESBs according to Haron et al. [107], who confirmed that knowledge was positively related to environmental attitudes, behaviours, and participation. In other words, the more the knowledge acquired about energy saving, the more likely that individuals engage in energy saving. Conversely, the poorer the knowledge about energy saving, the more difficult the development of energy-saving behaviors. Most scholars have neglected the direct link between energy-saving knowledge and HESBs [49]. Extensive environmental education to increase knowledge of energy saving may help to increase awareness of energy conservation, but it does not directly lead to HESBs. Hence, it is also plausible that knowledge about energy conservation solely raises awareness of energy conservation without necessarily resulting in the adoption of energy-saving behaviors (HESBs).

5.1.4. Subjective norms

Subjective norms exerted a greater effect on CESBs than did the value of energy conservation, subjective norms are considered a direct determinant of behavior [108]. However, will and norms do not entirely control human behavior, because it also hinges on external factors like resources, opportunities, and abilities. In this study, the questionnaire reflected that approximately 57.6 % (295/512) of the students perceived that many of their classmates adapted energy-saving and that they were significantly influenced by the people around them in terms of energy-saving behaviors. Although the TPB only partially explained why subjective norms are formed in humans, social psychological theory believed that subjective norms exert a greater impact on behavior than do attitudes on behavior. Generally, if individuals possess a favorable subjective norm, their drive to partake in the behavior intensifies. Additionally, individuals with robust intentions often partake in such behavior when presented with the chance [92]. Therefore, strengthening norms toward energy saving in colleges and universities can be a positive direction for students in developing energy-saving behaviours.

5.1.5. Perceived self-efficacy

Subjective norms and perceived self-efficacy influenced IESBs in which subjective norms exerted a greater impact on IESBs than did perceived self-efficacy, which suggests that the more socially compliant the students, the more likely they are to positively guide the development of energy-saving behaviors in others. In addition, Chinese university students tended to live in group dormitories on campus and participate in group living. As such, students who maintain non-energy-efficient behaviors may be rejected en masse. Other students may consciously hide their non-energy-efficient values with a focus on self-enjoyment. The survey highlighted their self-centered values, showing that the significance of energy conservation and understanding about energy saving didn't notably influence Individual Energy-Saving Behaviors (IESBs). Additionally, the prevalent lack of awareness on energy conservation and inadequate emphasis on the importance of energy saving in Chinese universities might lead many students to view the adoption of Individual Energy-Saving Behaviors (IESBs) as less meaningful.

5.1.6. Intention of saving energy

The intention to save energy partially served as a mediator in the connection between comfort preference and HESBs, as well as between the value attributed to energy conservation and HESBs. Additionally, the intention to save energy was crucial in connecting comfort preference and the value of energy conservation to HESBs. The intention to conserve energy also acted as a mediator between comfort preference and energy-saving value in relation to HESBs. The present study's outcomes align with previous research findings [46,49], further affirming the mediating effect of the intention to conserve energy. In other words, the intention of energy saving is influenced HESBs, CESBs, and helped to convert comfort preference to HESBs and CESBs. However, other scholars [27] argued that intention exerted a finite influence on ESBs.

5.2. Policy implications

According to the abovementioned behavioral causality conclusions and united the features of university students, our current study puts forward policy implications for university administrators for promoting the positive growth of ESBs among students.

5.2.1. Optimize equipment energy management and establish reasonable energy management policies to meet the flexible energy needs of college students and create an external environment that promotes energy conservation

Comfort preference exerts a significant impact on HESBs and is a factor that cannot be overlooked. Thus, the study concluded that university students have a high demand for comfort, which makes it difficult for them to accept energy savings at the expense of comfort [109]. Du [110] found that students perceive that the overheating of the room will moderate energy-saving behavior, such that the arrangement of equipment in existing school environments should be enhanced to accommodate the unique climatic characteristics of the region, experiencing both hot summers and cold winters. Additionally, this arrangement should consider variations in energy demand throughout the year. For instance, indoor air conditioning temperatures should not be set below 26 °C in summer and above 20 °C in winter to align with energy-saving and environmental protection requirements.

Students who experience greater satisfaction with their indoor environment are more inclined to conserve energy and are more likely to engage in energy-saving actions. In response to the comfort needs of students, it is essential to establish an indoor environment that aligns with human comfort standards, including the implementation of humidity and temperature regulators in rooms, reasonably arranged ventilation systems, and lighting systems. Extremely temperatures and humidity levels not only discourage energy-saving behaviors among students but also have a negative impact on their learning efficiency.

5.2.2. Establish energy-saving incentive policies to encourage energy conservation from an institutional perspective

In order to promote the transition of college students towards energy-saving behavior, more effective incentive policies should be considered for college students to reduce carbon emissions. Both material and spiritual rewards will have different motivational effects. Our questionnaire survey demonstrated that 60.94 %(312/512) of the students have willingness to conserve electricity if incentives are given for energy-saving activities. Qalati et al. [111] found that the energy use of participants can be reduced when incentives are adopted. A few universities previously initiated the implementation of incentive systems for energy-efficient dormitories. For example, excellent energy-saving dormitories or groups may be awarded through a review to receive a comprehensive test credit award or other forms of incentives.

5.2.3. Energy saving publicity and education policies should be formulated to strengthen the promotion of carbon reduction and energy saving

At present, the majority of energy-saving campaigns and educational efforts by universities are largely in textual format, which has limited impact on fostering energy-saving habits in students. From the survey results, 333 of the 512 students believe that institutions should intensify energy-saving advocacy, and 64.45 % (330/512) expressing a willingness to participate in related events. Consequently, it is imperative for universities to enhance their advocacy and education efforts pertaining to energy conservation, organize relevant activities, and offer courses on energy management for sustainable development.

Colleges should focus on teaching knowledge about systematic energy saving to students. Universities that can do so can offer courses on energy saving management such as environmental management, environmental economics, resource economics, development economics, and development sociology.

Engaging in a variety of energy-saving activities on campus and participating in related social initiatives can inspire students to conduct surveys and field studies on campus energy conservation. Additionally, they can mobilize youth volunteers to collaborate with the community in organizing promotional and educational events. Through active involvement in these social activities, students are motivated to acquire knowledge about energy conservation, thereby gaining an understanding of its significance and value. This will help them grasp the importance and value of energy saving and become effective contributors to an energy-efficient campus. The main force behind building an “energy efficient” campus.

Using a wide range of resources to promote relevant campaigns should fully utilize the modern means of publicity, such as school newspapers, billboards, radio, and websites, to promote national energy policies and knowledge about energy saving. For example, the current study established a dedicated section on university forums aimed at guiding students towards adopting sustainable energy-saving practices.

6. Conclusion

This study focused on university students residing in the region of China known for its hot summers and cold winters. Its objective was to explore the determinants of their energy-saving actions, employing the Theory of Planned Behavior (TPB) framework within the context of their current environment. The factors considered are comfort preference, values of energy saving, subjective norms, knowledge of energy saving, and perceived self-efficacy. Drawing from a comprehensive literature review and previous research, a simplified model of Energy-Saving Behaviors (ESBs) for university students was formulated and influencing factors were defined. A questionnaire survey is conducted on universities in hot summer and cold winter regions of China, aiming to understand the important factors that affect students’ campus energy-saving behaviors and behavioral intentions. From July to August 2022, 512 survey responses were collected from various university campuses situated in the hot summer-cold winter weather zone of China. The survey included questions on subjective norms, understanding of energy conservation, and the importance of saving energy. Through Structural Equation Modeling (SEM) analysis, paths of influence regarding factors impacting energy-saving behaviors were examined. The primary conclusions can be outlined as follows.

(1) Comfort preference, values of energy saving, subjective norms, knowledge of energy saving, and perceived self-efficacy exerted different effects on ESBs. In particular, the values related to energy conservation and subjective norms emerge as significant drivers. Values associated with energy conservation and subjective norms displayed positive effects on CESBs. Additionally, values of energy saving positively influenced HESBs, while subjective norms had a positive impact on IESBs.

(2) The influencing factors of ESBs of college students showed different influences under different energy-saving behaviors. The intention of energy saving played a partial intermediary effect in the path of “comfort preference → intention of energy saving → HESBs” and “values of energy saving → intention of energy saving → HESBs”, whereas the impact on CESBs and IESBs is not clearly evident.

(3) ESBs are influenced not only by the direct effects of comfort preference and value of energy saving but also by the mediating effects of intention to conserve energy.

This research focus on examining the varying impacts of factors affecting the ESBs of university students, which enriches the research on the energy-saving behaviors of this group. At the same time, based on the research results, corresponding policy recommendations have been proposed, such as suggesting that universities and government management departments should optimize equipment energy management and designate reasonable energy management policies to meet the flexible energy needs of college students, establish energy-saving incentive policies, encourage energy conservation from an institutional perspective, formulate energy-saving publicity and education policies, and strengthen the promotion of carbon reduction and energy conservation. The research results can help college administrators in formulate develop effective plans for energy management and provide theoretical references for creating sustainable campuses.

7. Limitations and perspectives

This study has its limitations that should be addressed in the future research. The first pertains to the areas in which the questionnaire is distributed. The effective sample of the questionnaire is 512. While this study includes a notable array of provinces and major cities situated in China's region characterized by hot summers and cold winters, it is essential to note that these areas may not fully represent all similar regions. Therefore, a deficiency is noted in regional distribution. In future studies, two potential avenues for addressing this limitation are identified. Firstly, there is a need for an increased number of data samples from cities located in regions characterized by hot summers and cold winters in order to enhance the generalizability of the findings. Secondly, it is essential to further categorize different climatic zones based on the indoor thermal comfort requirements of various regions within these hot-summer and cold-winter areas, thus enabling more comprehensive investigations. Additionally, consideration should be given to the demographic composition of the surveyed population; while university students from regions with hot summers and cold winters were specifically targeted for this study, it is possible that some individuals may originate from outside of these climatic zones. As such, they will be influenced by the living habits and characteristics of their regions, which could lead to certain deviations in the results. It means that different people from different provinces in China have been influenced by a specific cultural background and they couldn't change their energy saving customs immediately. Future studies need to conduct in-depth surveys and increase in-depth one-on-one interviews with individuals from diverse cultural backgrounds in order to thoroughly investigate the variations in energy-saving behaviors and their impact on energy consumption across cultures. This will contribute to enhancing the findings can be extrapolated to similar climate zones in the future, such as those with hot summers and mild winters, thereby promoting energy conservation and emission reduction among college students.

Data availability statement

Data will be made available on request.

Ethics statement

Approval by an ethics committee was not required for this study as per applicable institutional and national guidelines and regulations. That is, why we cannot provide a formal approval by the institutional ethics committee. Participating students fill out the questionnaire anonymously and without privacy concerns. If students did not want to participate, they could abandon filling out the questionnaire. All participating students expressed their willingness to participate in this activity.

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CRediT authorship contribution statement

Jiasheng Li: Writing – original draft, Software, Investigation, Data curation. **Yinxin Zeng:** Writing – original draft, Visualization, Investigation, Formal analysis. **Zhipan Gu:** Writing – review & editing, Supervision, Project administration, Methodology, Conceptualization. **Hongyao Chen:** Writing – original draft, Investigation, Data curation. **Xiao Chen:** Writing – original draft, Investigation, Data curation. **Dongjin Zou:** Investigation, Data curation. **Yudie Liu:** Resources, Funding acquisition. **Liyuan Deng:** Writing – original draft.

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e36995.

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