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Articles

A hybrid PLS-SEM-neural network approach to determine the factors affecting the purchasing intention of energy efficiency home appliances

Un enfoque híbrido que combina PLS, SEM e redes neurais para determinar os factores que inflúen na intención de compra de electrodomésticos de baixo consumo

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Abstract

Household appliances are among the most frequently purchased products and contribute significantly to household energy consumption. As everyday devices used for routine domestic activities, many appliances require substantial amounts of electricity, making energy-efficient alternatives increasingly important for promoting sustainable consumption and reducing residential energy use. This study examines the determinants influencing householders' purchase intentions toward energy-efficient home appliances. The research is grounded in the Theory of Planned Behavior (TPB), exploring the relationships among attitude, subjective norms, perceived behavioral control, and purchase intention, while also incorporating additional psychological factors such as self-expressive benefits and environmental knowledge. Furthermore, the study investigates the mediating role of environmental knowledge in shaping consumer purchase intentions. Data were collected from 398 respondents using a non-probability purposive sampling technique, and the analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM). The findings indicate that attitude, subjective norms, and perceived behavioral control have a positive and statistically significant influence on purchase intention toward energy-efficient appliances. Self-expressive benefits significantly influence consumers' attitudes and indirectly affect purchase intention through attitude. However, environmental knowledge does not moderate the relationships between attitude and purchase intention or between perceived behavioral control and purchase intention. In addition, the Artificial Neural Network (ANN) analysis reveals that attitude is the most influential predictor of purchase intention, followed by subjective norms and self-expressive benefits, while environmental knowledge plays a comparatively weaker role, suggesting that economic and behavioral considerations remain stronger drivers of consumers' purchasing decisions than environmental awareness alone.

Keywords: PLS-SEM; Artificial neural network; Purchasing intention; Energy efficiency home appliances; Theory of planned behaviour.

Resumo

Os electrodomésticos atópanse entre os produtos que máis compran e contribúen de maneira significativa ao consumo enerxético dos fogares. Ao tratarse de aparellos de uso cotián para as actividades domésticas habituais, moitos deles consomen cantidades considerables de electricidade, o que fai que as alternativas enerxeticamente eficientes cobren cada vez máis importancia para promover un consumo sostible e reducir o consumo enerxético residencial. Este estudo analiza os factores que inflúen na intención de compra dos fogares de electrodomésticos de baixo consumo. A investigación baséase na Teoría do Comportamento Planificado (TPB) e explora as relacións entre a actitude, as normas subxectivas, o control conductual percibido e a intención de compra, á vez que incorpora factores psicolóxicos adicionais, como os beneficios da autoexpresión e o coñecemento medioambiental. Ademais, o estudo investiga o papel mediador do coñecemento medioambiental na configuración das intencións de compra dos consumidores. Os datos recompiláronse de 398 enquisados mediante unha técnica de mostraxe intencional non probabilístico, e a análise levou a cabo utilizando o modelo de ecuacións estruturais de mínimos cadrados parciais (PLS-SEM). Os resultados indican que a actitude, as normas subxectivas e o control conductual percibido exercen unha influencia positiva e estatisticamente significativa na intención de compra de electrodomésticos de baixo consumo. Os beneficios de autoexpresión inflúen significativamente nas actitudes dos consumidores e afectan indirectamente á intención de compra a través da actitude. Con todo, o coñecemento medioambiental non modera as relacións entre a actitude e a intención de compra, nin entre o control conductual percibido e a intención de compra. Ademais, a análise da rede neural artificial (RNA) revela que a actitude é o predictor máis influente da intención de compra, seguida das normas subxectivas e os beneficios de autoexpresión, mentres que o coñecemento medioambiental desempeña un papel comparativamente máis débil, o que suxire que as consideracións económicas e de comportamento seguen sendo factores máis determinantes das decisións de compra dos consumidores que a mera conciencia medioambiental.

Palabras chave: PLS-SEM; Rede neural artificial; Intención de compra; Electrodomésticos de baixo consumo; Teoría do comportamento planificado.

JEL Classification: D12; D91; Q41; Q56; M31.

1. Introduction

Worldwide, governments have made much of the importance of citizens' responsibility for their local environment. This is characterized by decreased power consumption (Ek & Söderholm, 2010). When it comes to energy, it has been considered an issue and a serious problem all over the world. The efficient utilization of energy in households is a significant key towards national security in energy, climate change prevention, and the reduction of greenhouse gas emissions (Nguyen & Nguyen-Ngoc, 2025). Energy consumption is high in household appliances, so the demand for households to buy energy-saving models is a prime example of how to use energy efficiently and economically (Guan & Lin, 2025; Nguyen & Nguyen-Ngoc, 2025). During the United Nations Sustainable Development Summit, all 193-member states agreed to adopt the United Nations Sustainable Development Goals (SDGs), a global framework designed to address major economic, social, and environmental challenges in an integrated manner and to promote sustainable development by the year 2030 (Shang et al., 2023; Donato & Adıgüzel, 2022; Wang et al., 2021). These goals emphasize the importance of meeting present developmental needs while ensuring that the ability of future generations to meet their own needs is not compromised (Shang et al., 2023; Wang et al., 2021). In response to this global agenda, sustainable consumption—often referred to as green consumption—has increasingly become a key area of focus for governments, businesses, and individuals worldwide. Growing awareness of environmental challenges and resource limitations has led to greater interest in adopting consumption patterns that support environmental sustainability and responsible resource use (Donato & Adıgüzel, 2022; Shang et al., 2023; Wang, Pacho, et al., 2019).

Home appliances like air conditioners, refrigerators, etc., account for the largest components of energy use and carbon emissions (Wang, Pacho, et al., 2019). He added that household appliances contribute to 70% of household CO2 emissions, among which air conditioning, refrigerator, and TV contribute half of the total. Herein, Guan & Lin (2024) and Olsthoorn et al. (2023) urged the adoption of energy-efficient home appliances (EEHA) to reduce energy consumption and carbon dioxide emissions. Thus, the purchasing intention of EEHA encompasses a positive impact on energy use within the household and may cultivate positive buying behavior. Therefore, this purchase needs further investigation (Nguyen & Nguyen-Ngoc, 2025; Lin & Dong, 2023; Olsthoorn et al, 2023). High-efficiency electrical home appliances that are manufactured by modern technology will reduce the usage of power (Tan et al, 2017), such as refrigerators and air conditioners.

Encouraging households to have EEHA is also good for the household sector as this would contribute to environmental sustainability and energy saving (Olsthoorn et al, 2023; Ali et al., 2019; Guan & Lin, 2024). It is generally believed that lower energy consumption and higher efficiency are the most positive, quickest, cheapest, and safest means of relieving environmental degradation and global warming (Zhou & Yang, 2016). Consumers' demand for five-star-rated energy-efficient appliances at home could also go a long way in determining the purchasing behavior of these energy-efficient consumers because they have more to offer than traditional appliances in terms of energy efficiency and sustainability. Further, they do not need ongoing effort from customers as it is a single investment (Frederiks et al., 2016).

Tan et al. (2017) figured that people can lessen negative environmental impacts by purchasing EEHA. Additionally, energy-saving offerings benefit the economy and environment. Wang et al. (2017) claimed that household appliances contribute to 70% CO2 emissions, whereas TVs, refrigerators, and air conditioners contribute to 50% CO2 emissions. Consumers favor those products of companies that show themselves as eco-friendly and corporate socially

responsible (Shang et al., 2023). Some organizations also develop social reputation and realize environmental performance by integrating ethical action into organizational strategy and environmental strategy (Sarker et al., 2019).

Energy-efficient equipment requires less energy than conventional ones for a similar output and hence offers the corresponding performance, convenience, and comfort (Tan et al., 2017). Thus, since traditional appliances are a cause of an increase in emissions and energy use, investment in high-efficiency equipment products is necessary (Joshi et al., 2020). However, the concepts "energy efficiency" and "energy conservation" hold different meanings. Energy efficiency is a reduction in direct energy use through new technology (Poortinga et al., 2003), whereas energy management refers to the change in technology or human behavior aimed at conserving electrical resources. Consumer behavior change is a prerequisite to successful implementation for EEA, but not for EE (Oikonomou et al., 2009).

Countries around the world are focusing on green energy to support and sustain natural resources for a brighter future. In Saudi Arabia, the consumption of electricity accounts for more than a third of its daily oil production. Studies have demonstrated the extent to which buildings in KSA are exposing themselves as a challenge, with the high rate of electricity consumption, which is mainly used for air conditioning (AC) units, has been estimated at 70% of electricity consumed. According to a government report, refrigerators were found to consume approximately twice as much electricity as air conditioners during an average week, highlighting their substantial contribution to household energy consumption (Felimban et al., 2019). In response to growing concerns about residential energy use, researchers have increasingly examined consumer purchasing behavior related to energy-efficient home appliances (EEHA). A considerable body of research has focused on developed economies such as the United Kingdom, the Netherlands, Australia, and the United States (Abrahamse & Steg, 2009; Baldini et al., 2018; Ek & Söderholm, 2010). Similarly, studies conducted in emerging economies—including Malaysia, China, Vietnam, and India—have explored the determinants influencing consumers' adoption of energy-efficient technologies (Jain & Kaur, 2006; Li et al., 2021; Tan et al., 2017; Zhang et al., 2019). Despite this growing body of literature, research examining these issues within the Saudi Arabian context remains limited. Given that countries differ significantly in terms of socioeconomic conditions, energy policies, and resource availability, consumer preferences and technology adoption patterns may vary accordingly. Therefore, investigating the barriers and motivations influencing the adoption of energy-efficient technologies—particularly photovoltaic-thermal (PVT) technologies—in Saudi Arabia remains an important research gap.

Previous studies have also explored factors influencing consumers' intentions and behaviors regarding the purchase of energy-efficient home appliances by focusing on individual values and perceptions. For example, Lin and Dong (2023) reported that attitude, subjective norms, and perceived behavioral control significantly and positively affect consumers' intentions to purchase EEHA in Taiwan. Similarly, Waris and Hameed (2020) applied the Theory of Planned Behavior (TPB) to examine purchase intentions for energy-efficient appliances in Pakistan and found that attitude, subjective norms, and perceived behavioral control were significant predictors of purchasing intention. Furthermore, Harun et al. (2022) confirmed the relevance of TPB constructs in explaining the adoption of energy-efficient appliances in Malaysia, highlighting the significant roles of attitude and normative influences.

Wang, Sun, et al. (2019) find that consumers' purchase intent was influenced by consumers' buying attitudes on energy-saving products, personal norms, and subjective norms. Basiru et al. (2024) found that the attitude towards energy-efficient appliances (EEAs) and PBC had a positive and significant impact on the intention to use EEAs. The subjective norm (SN) was found to be insignificant. Nguyen & Nguyen-Ngoc (2025) demonstrate how ATT, PBC, and SN

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positively influence consumers' purchase intentions for EEHA in Ho Chi Minh City, Vietnam, as the independent constructs. Arora and Varah (2025) identify the same findings in the Indian context. Furthermore, Jia et al. (2024) extracted related findings in the Pakistan context.

Bhutto et al. (2022) extended the TPB model. They used the model to predict young consumers' purchase intention towards EEHA in the Pakistani context. According to the results of this study, the self-expressive factor has a low impact on attitude. Meanwhile, the mediation effect remained insignificant with the given insignificant relationship between self-expressive benefits and purchase intention.

Liao et al. (2020) examined the impact of self-expressive benefits in energy-saving products that positively affect energy-saving appliances. Hartmann and Apaolaza-Ibáñez (2012) did not show a positive relationship between self-expressive value vis-à-vis brand attitude and purchase intention. Boobalan et al. (2021) examined the mediating effect of attitude between self-expressive benefit and purchase intention. We clearly found it from mediation analysis that attitude acts as a mediatory variable between self-expressive benefit and purchase intention for the entire sample, at both the country (India & USA) level. But attitude did not emerge as a mediator between relationship self-expressive benefits and purchase intention in the case of the Indian sample only.

Consumers' desire to buy energy-saving products is deeply affected by their environmental awareness. Increasing public knowledge and providing environmental education are easy approaches to enhance environmental knowledge (Hossain, Fekete-Farkas, et al., 2022). Shahzad et al. (2022) asserted that knowledge was recognized to be the most relevant factor among the factors of green technology adoption, especially for energy efficiency home appliances. Li et al. (2021) found that the impact of environmental knowledge was not significant as a moderating effect between attitudes and purchase intention on energy-saving home appliances. Wang, Sun, et al. (2019) also included and verified that knowledge plays a positive moderating role in the construct of subjective norm and attitude with purchase intention.

As such, in order to fill up the gaps identified above in the literature, this study explores what determines Saudi Arabian purchasing intention of energy efficiency appliances. The current paper contributes to the literature in two aspects: a new setting and novel variables. The present study wishes to observe the essential elements of Saudi Arabian consumers' purchase intention that will expand our understanding of energy efficiency appliances purchase in a developing country context. With respect to the new variables, this study applies the TPB model along with introducing some other constructs like Self-Expressive Benefit and environmental knowledge. The environmental value was introduced as the schema variables of the attitude, subjective norm, and perceived behavioral control on buying intention. As a mediator, the attitude was analyzed between self-expressive benefit and purchase intention. The study investigated purchasing energy-efficient appliances, which is rare in marketing research for integrating both PLS-SEM and ANN.

2. Literature review and hypotheses development

2.1 Theory of Planned Behavior (TPB)

TPB was introduced by Ajzen (1991), who posited that people think about their behavior before they act. The TPB offers a method to test determinants of behavior (Hameed et al., 2021). It is also evident in the theory that the behavior of an individual is predicted by their intention, and this, in turn, would be driven by attitude toward performing the behavior, subjective

norms, and perceived behavioral control. In simpler terms, the TPB has it that when individuals make up their minds to perform a certain behavior, they are more likely to actually do said behavior. TPB has been applied to many environmentally responsible behaviors, including low-energy appliance use (Arora & Varah, 2025; Jia et al., 2024; Li et al., 2019). Although several criticisms have been raised against the TPB model, in the field of pro-environmental behavior, it has been strongly supported (Basiru et al., 2024; Waris et al., 2023). The principal criticism is of the fact that it lends itself ineluctably to refinement by supplementing with more relevant terms: duller and drearier than an all-terrain MUP, or a substrate for further wax-like function creep (Arora & Varah, 2025; Alzubaidi et al., 2021).

There is evidence from some research that the TPB may not explain intention variance fully (Al Mamun et al., 2019). Ajzen (2020) noted that the TPB permits additional constructs if they account for a substantial portion of variance in behavior. It is for this reason that several researchers have advocated for incorporating other variables that would affect intention to enhance the TPB explanatory power (Kaffashi & Shamsudin, 2019). In doing so, the present study extends the TPB model through the incorporation of signaling theory: in "self-expressive benefit", consumers can derive psychological utility when they are able to engage in observable consumption behavior that is eco-friendly (Aaker, 1999). This enhanced stimulation results in heightened exposure to the specific behavior (Bennett & Chakravarti, 2009). Furthermore, the present study also examines environmental knowledge as a moderator. Our study develops and empirically validates the model of EEAs adoption of sustainable consumption in Saudi Arabia to enhance its predictive power.

2.2 Attitude

Attitude refers to positive and/or negative feelings that individuals have toward someone or something. Consequently, attitude is the result of internal systems and some experiences (Ajzen, 1991). Yeow and Loo (2022) supported this view, calling it an assessment of the individual's positive and negative affective feelings in specific situations. Consumers' attitude related to the use of energy goods in their homes is presented as attitude, which specifies a preliminary estimate of propensity for them towards saving (Lin & Dong, 2023, and Alzubaidi et al., 2021). Each of these facets is an essential component of environmental marketing research and has been found by prior environmental marketing researchers to affect the intention of people to conserve energy, which can rightly be linked with intentions to buy energy-saving household appliances (Nguyen & Nguyen-Ngoc, 2025; Basiru et al., 2024; Kang & Moreno, 2020). Attitude towards purchase intention on energy-efficiency home appliances was found to be positive and significant (Nguyen & Nguyen-Ngoc, 2025; Basiru et al., 2024; Lin & Dong, 2023). From this discussion, we formulate our hypothesis.

> H1: Attitude positively influences consumers' purchase intentions for energy-efficient appliances.

2.3 Subjective norms

Subjective norms entail perceived social pressure to perform or not perform some behavior (Ajzen, 1991). An individual's subjective norms, also known as social influence factors, are often influenced by the values and behavior of others. Subjective criteria need to be taken into consideration by an individual if he or she decides to use an environmentally friendly product (McBride et al., 2020; Saut & Saing, 2021). Nguyen & Nguyen-Ngoc (2025) report that subjective norm towards intention to purchase energy-saving home appliances was significant and

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positive. Their subjective norm, as observed from the recent studies (Arora & Varah, 2025; Nguyen & Nguyen-Ngoc, 2025; Nogueira et al., 2023; Almrafee & Akaileh, 2024). Thus, we propose the hypothesis below.

H2. The subjective norm has a significant positive effect on the consumers' purchasing intentions of energy-efficient appliances.

2.4 Perceived behavioral control

The TPB construct with the highest importance to predicting consumers' environmental purchasing is perceived behavioral control. Ajzen (1991) conceptualized "perceived behavioral control" (PBC) as ease of acting. In the green marketing context, PBC anticipates eco-awareness among consumers (Nogueira et al., 2023). Hameed et al. (2021) argue that the level of income, price of commodities and/or services, as well as entry opportunities, can affect behavior. If individuals were unable to analyze these components, the effect of PBC on behavioral intention would be reduced. The previous research has also found that PBC is a core determinant of behavioral intention in energy efficiency products (Nguyen & Nguyen-Ngoc, 2025; Nekmahmud & Fekete- Farkas, 2020). If individuals do not feel in charge of their actions, it has a direct impact on their behavior. One such meta-analysis of TPB studies showed no significant relationship between perceived behavioral control and real behavior when the subjects had total control over the behavior, meaning that intention alone predicted behavior (Shin et al., 2020).

But some customers may not be able to afford, wait for, or even have access in their area to more energy-efficient appliances. The actual control exactly matches the perceived behavioral control for the direct effect. Lin and Dong (2023) reported that attitude had a significant positive impact on the purchasing intention of energy-efficient home appliances. Arora & Varah (2025); Nguyen & Nguyen-Ngoc (2025); Hossain, Nekmahmud, et al. (2022) have recently empirically confirmed that PBC is a key determinant of energy-saving household appliance decision to purchase. Perceived behavioral control (PBC) as an important antecedent was also taken to be a significant predictor of eco-friendly purchase behavior (Lin & Dong, 2023) and received increased attention by firms for their environmental marketing activities. We then propose the glancing hypothesis.

H3. Perceived behavioral control has a positive effect on consumer intention to purchase energy-efficient appliances.

2.5 Self-Expressive Benefit and Attitude

Self-expressive and customers' psychological needs concern participation, external ego identity (Keller 1993). Nothing but benefits search for consumers to already be satisfied, which also takes into consideration the environment of others (Hartmann & Apaolaza Ibáñez, 2006). The altruists' approach claimed that social status, reputation, and ability to expend resources motivate consumers in public engagement (Van Vugt et al., 2009). Tangible possessions remained symbolic and were expected to contain the effects of purchase and consumption (Sirgy, 1985). Griskevicius et al. (2010) claimed that status motivation would induce consumers to prefer environmentally friendly over conventional items.

A self-described positive and significant relationship has a positive relationship with attitude (Boobalan et al., 2021). However, sub-par effect has been shown through attitude (Bhutto et al. 2022; Hartmann and Apaolaza-Ibáñez 2012). Based on prior research, this study suggests that EEHA would predict psychological benefits and experience of supporting

consumer attitudes toward socialism and environmentalism, resulting in the willingness to pay more for society and the environment. Hence, this study assumes that self-expressive benefits might positively influence consumers' attitudes toward EEAs. Thus, the study proposes the following hypothesis.

H4: The self-expressive benefits have a positive effect on consumer attitudes towards energy-efficient appliances.

2.6 Attitude as a Mediator

Previous research has highlighted the mediating role of attitude in shaping the relationship between environmentally friendly products and consumers' purchase intentions (Afroz et al., 2015; Al Mamun et al., 2019). Similarly, Gadenne et al. (2011) emphasized that environmental norms and antecedents, along with social and community influences, significantly contribute to the formation of attitudes that ultimately guide environmentally responsible behavior. In the context of energy-efficient appliances, Bhutto et al. (2022) examined the mediating role of attitude in the relationship between self-expressive benefits and purchase intention. Their findings revealed no significant direct relationship between self-expressive benefits and purchase intention for energy-efficient appliances. The study further suggested that young consumers in Pakistan generally do not perceive eco-friendly appliances as products that enhance their social image or status. Consequently, the results indicated that attitude did not function as a significant mediator between self-expressive benefits and purchase intention in that context.

In contrast, Boobalan et al. (2021) explored the mediating influence of attitude between self-expressive benefits and purchase intention across samples from India and the United States. Their results showed that attitude played a significant mediating role for the overall sample and for the U.S. respondents. However, the mediating effect was not supported for the Indian sample, suggesting that cultural or contextual differences may influence the relationship between self-expressive benefits and consumer behavior.

Other studies have also examined factors that shape attitudes toward energy-efficient technologies. For instance, Ali et al. (2019) utilized the Technology Readiness Index (TRI), which includes dimensions such as optimism, innovativeness, insecurity, and discomfort, to explain attitudes toward energy-saving products. Their findings indicated that optimism and innovativeness positively influence attitude formation, whereas insecurity and discomfort weaken positive attitudes toward adopting such technologies. Moreover, attitudes were found to significantly influence consumers' intentions to purchase energy-saving products. Building on these insights, the present study seeks to further explore how self-expressive benefits influence consumers' purchase intentions toward energy-efficient appliances through the mediating role of attitude. Therefore, the following hypothesis is proposed.

H5: Attitude toward energy-efficient appliances mediated the relationship between self-expressive benefits and purchase intent of energy-efficient appliances.

2.7 Environmental knowledge as a moderator

Consumers' knowledge affects their behavior, leading to better information search and purchase decisions. Environmental knowledge (EK) is an individual's environmental know-how, awareness or inability (Li et al., 2021). Previous studies show that environmental knowledge positively influences consumer beliefs and attitudes concerning green product

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consumption (Li et al, 2021; Choi & Johnson, 2019; Suki, 2013). Wang, Pacho, et al. (2019) observed the positive moderation of knowledge between subjective norm and attitude toward purchase intention. But distrust in green goods keeps consumers from buying them. Such skepticism arises from the fear that labels or advertising could potentially overclaim and mislead consumers as to what is contained within the product (Goh & Balaji, 2016). Moreover, consumers are considered to be not well-informed as they lack information regarding green products (Higueras-Castillo et al., 2019), and the awareness of environmental issues and climate change (Kardooni et al., 2016). Thus, the absence of knowledge names a situation where consumers have the fewest opportunities to make an informed decision to buy green products like energy-saving appliances (see Larson et al., 2014).

Hamzah and Tanwir (2021) figured that environmental knowledge did not moderate the relationship between ATT, SN, PBC, and purchase intention. Similarly, Choi and Johnson (2019) claimed that consumers with environmental knowledge are interested in green purchases. However, Levine and Strube (2012) argued that attitude did not significantly affect pro-environmental intentions. It remained significant when Li et al. (2021) applied the bootstrapping technique on the moderating role of environmental knowledge between ATT towards purchase intention of EEHAs. The result remained insignificant. Hence, PEK is suggested to have a positive moderating role in determining the relationship between attitude, Subjective norms, PBC, and green purchase intention. Hence, the study posits the following hypotheses.

H6. The influence of attitude toward purchase of energy-efficient appliances on purchase intention is stronger among high environmental knowledge consumers compared to the low environmental knowledge ones.

H7. The influence of Subjective norms towards energy efficiency appliances on purchase intention is stronger among those with higher environmental knowledge than those with lower environmental knowledge.

H8. The influence of perceived behavioral control toward energy-efficient appliances on purchase intention is stronger at a higher level than at a lower level of environmental knowledge.

3. Methodology

3.1 Instrument

This study seeks to understand the key determinants of consumers' purchase intention towards energy-efficient appliances by extending TPB. We collected data using a structured questionnaire and focused on Saudi Arabian consumers who have experience in buying energy-efficient appliances (e.g., AC's, refrigerators). The survey instrument is a two-section questionnaire to collect data from the respondents in this research. The demographics of the population were provided at the bottom (below), along with probes for variables of interest. Each item of the study was measured using a five-point Likert-type scale, with 1 (Strongly Disagree) to 5 (Strongly Agree). We have used the developed measurement instruments of previous researchers. The specific measurements used and sources are listed below.

3.2 Measures

The measurement items in this study were adapted from earlier studies. The adopted scale for behavioural intention includes three statements: 1) I plan on doing what I need to do in order use energy saving appliances, 2) When buying home appliances, I will only buy ones that are energy saving, 3) When switching to energy saving appliances, I would never go back to traditional appliances. Based on the work of Zhao et al., the statement used to measure perceived behavioural control included the following: 1) It's easy for me to obtain energy saving devices, 2) I have enough money to buy energy saving products, 3) I have complete control over whether or not I have energy saving appliances in my home.

Li et al.'s scale for environmental knowledge was modified for this study (examples were "As a consumer, I am more knowledgeable than most consumers regarding recycling" and "I follow the news regarding environmental issues"). The original items measuring subjective norm were developed by Bhutto et al. They included: "The people who are significant in my life believe that I should purchase energy-efficient products," "It's in vogue to use devices that conserve energy," and "The individuals whose opinions are valuable to me would prefer to buy energy-efficient products instead of traditional products." The attitude construct derived from Li et al. included: "I consider buying energy-efficient products a good habit," "I enjoy shopping for energy-efficient products," and "I believe that buying energy-efficient products is a good investment." The same items measuring self-expressive benefit were taken from Bhutto et al.: "By purchasing energy-efficient appliances, I am expressing my interest in protecting the environment," "Purchasing energy-efficient products represents my commitment to protecting the environment," and "By purchasing energy-efficient products, I am conveying to my friends that I care about the environment."

3.3 Sample and descriptive statistics

A web-based survey was used in the study. A non-probability purposive sampling technique was employed in this study to ensure that respondents possessed relevant experience with the purchase of energy-efficient home appliances. Only individuals who had previously purchased or seriously considered purchasing energy-efficient appliances (such as air conditioners or refrigerators) were invited to participate in the survey. The questionnaire was distributed online to household members and university-affiliated individuals across Riyadh. A total of 431 responses were initially collected; after data screening for incomplete responses and outliers, 398 valid questionnaires were retained for final analysis. This sampling approach is consistent with prior consumer behavior studies focusing on specialized product categories, where informed respondents are required.

A detailed demographic of respondents can be found in Table 1. The findings reported %male as 53% and %female as 47%. Regarding the age, the results indicated that for ages 20 to 30, the percentage was 21.4%, 18.8% for ages 31 to 40, 18.8%, from 41 to 50, 20.4%, from 51 to 60 20.1% and above 60, 19.3%. The results of household income indicated that less than 5000 SAR19.6%, from 5000 to 10000, 25.1%, from 10000 to 15000, 19.3%, from 15000 to 20000 17.6% and more than 20000, 18.3%. Regarding the level of education, bachelor 31.9%, master's level 36.2%, and PhD level 31.9%.

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Table 1. Detailed demographic information

Categories	Classification	Frequency	Percentage
Gender	Male	252	63.3
	Female	146	36.7
Age	20–34	133	33.4
	35–44	65	16.3
	45–54	82	20.6
	55–64	60	15.1
	Over 65	58	14.6
Education level	Diploma degree	130	32.7
	Bachelor's degree	168	42.2
	Postgraduate degrees	100	25.1
Monthly income	4000 to 9000	200	50.3
	10000 to 15000	119	29.9
	More than 16000	79	19.8

4. Analysis and Results

4.1 Common Method Bias (CMB)

The authors assess the presence of CMB because both the predictor and outcome were acquired from a single instrument. At the beginning, Harman's one factor was run, and data analysis resulted in the fact that a single factor can just explain 26.5 % of the whole variance. Because that is less than 50 % so, the CMB problem never arises.

To further demonstrate the nullity of CMB, we conducted the common latent factor test by re-specifying each indicator into a single-item second-order construct (Hew & Kadir, 2016). The outcome (Table 2) reveals that most of the method variances are small, indicating that there is a CMB signal in the measurement data, but that it is not huge.

Table 2. Common Latent Factor Analysis

Path	Substantive Loading	Substantive Variance	T-Statistic	Path Method Loading	Method Variance	T-Statistic (Method)
PI4	-0.2571	58.76%	-23.75	-0.0533	0.0076	1.53
PI3	-0.2586	57.72%	-23.25	0.0544	0.0038	1.86
PI1	-0.2216	54.19%	-21.64	-0.0792	0.0079	1.52
PI2	-0.2358	53.08%	-21.17	0.0685	0.0071	1.98
PBC1	-0.2020	52.34%	-20.85	0.0866	0.0047	1.96

Path	Substantive Loading	Substantive Variance	T-Statistic	Path Method Loading	Method Variance	T-Statistic (Method)
ATT2	-0.2249	49.97%	-19.89	-0.0764	0.0013	1.39
SN3	-0.1829	45.53%	-18.19	0.0929	0.0096	1.22
SN2	-0.2018	45.34%	-18.13	0.0271	0.0015	1.31
SEB1	-0.1793	44.93%	-17.97	0.0928	0.0045	1.60
SEB2	-0.1566	42.04%	-16.95	0.0085	0.0038	2.00
ATT1	-0.1952	41.99%	-16.93	0.0207	0.0037	1.56
ATT3	-0.1884	39.43%	-16.06	0.0006	0.0014	1.23
SEB3	-0.1675	38.68%	-15.81	-0.0225	0.0085	1.70
PBC2	-0.1491	34.28%	-14.37	0.0871	0.0045	1.85
SN1	-0.1772	31.67%	-13.55	0.0648	0.0080	1.04
PBC3	-0.1734	30.54%	-13.19	-0.0903	0.0057	1.47
EK1	-0.0933	7.83%	-5.80	-0.0857	0.0070	1.80
EK3	-0.0976	7.66%	-5.73	-0.0380	0.0065	1.99
EK2	-0.0939	7.05%	-5.48	0.0845	0.0089	1.81

4.2 Multivariate statistical assumptions

SmartPLS 4 was employed to analyze the proposed research model due to its suitability for variance-based structural equation modeling (PLS-SEM). This technique is particularly appropriate for exploratory research, complex models involving mediation and moderation effects, and datasets that do not meet multivariate normality assumptions. SmartPLS 4 also offers advanced bootstrapping procedures, improved graphical visualization, and enhanced computational efficiency compared to earlier versions. Given the study's objective to assess both predictive relationships and indirect effects, SmartPLS 4 provides a robust and reliable analytical platform.

Several different conditions must be met before multivariate analysis can occur. The multicollinearity issue was checked by VIFs and Tolerances, see Table 3. As the VIF values fall within 1.00–1.82, which is below the normal cutoff of 10, there is no multicollinearity problem (Hew & Kadir, 2016).

Table 3. Multicollinearity

Construct	VIF
Attitude	1.44
Environmental Knowledge	1.19
Perceived Behavioral Control	1.82
Self-Expressive benefit	1.00
Subjective Norms	1.76

After checking homoscedasticity based on the standard residual scatter plot (Figure 1), authors observed that the residuals are scattered along a diagonal. Thus, homoscedasticity remains verified. Using a one-sample Kolmogorov-Smirnov test, the normal distribution is

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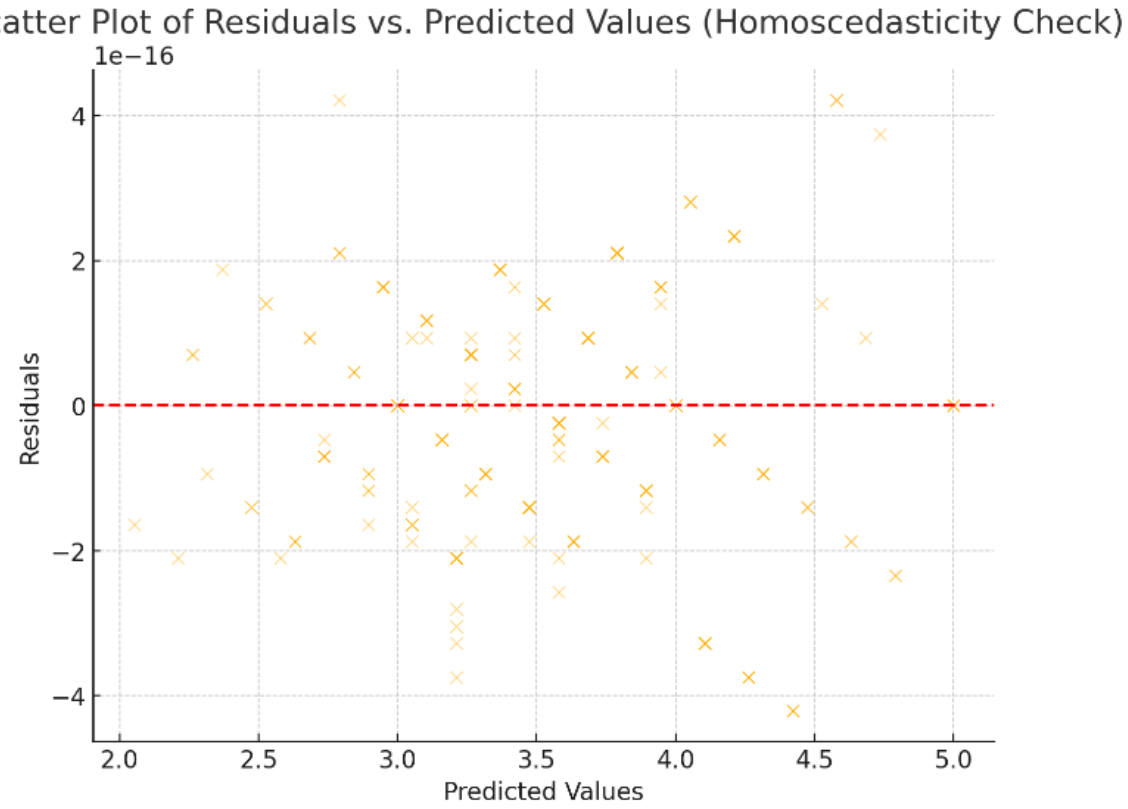
tested. Having all p-values below 0.05 indicates that the data distribution needs to be normal. Hence, partial least squares (PLS) variance-based SEM are used because PLS is robust against non-normal distribution in relation to covariance-based SEM (Leong et al., 2019). The authors used Ringle et al.'s (2015) SmartPLS 4 to test the hypotheses in the research framework. Additionally, an ANN analysis was performed in order to rank the standardized importance of the significant predictors according to PLS analysis. Application of SEM-PLS-ANN in two stages would be complementary, as the second stage (ANN) to cover the other business question is not feasible for conducting hypothesis testing on linear relationships, while SEM-PLS can deal well with linear relationships but cannot capture non-linear relationships. The ANN can identify non-linear relationships, but not suitable for hypothesis testing due to "black box" operation (Hew et al., 2016).

Figure 1. Residuals vs. Predicted Values



4.3 Measurement model

First, hypothesis tests were conducted using SmartPLS 4, including a bootstrapping with 5.000 resamples employing the no sign change option in the first step. A one-tailed test at a quantile of 0.05 was used. From the PLS algorithm, we also tested its reliability and validity. All Cronbach's alpha and composite reliability are greater than 0.70 (Table 4). Authors additionally announce that the measurement model of the construct is highly reliable (Hew et al., 2018). In the case of convergent validity, the value of average variance extracted (AVE) exceeds 0.50, signaling that the items converge strongly on their respective constructs. It means that construct validity is established (Nordman & Tolstoy, 2016).

Table 4. Reliability and Convergent Validity

	Cronbach's Alpha	rho_A	CR	AVE
Attitude	0.80	0.80	0.88	0.72
Environmental Knowledge	0.74	0.74	0.73	0.67
Perceived Behavioral Control	0.71	0.72	0.84	0.63
Purchase Intention	0.83	0.83	0.90	0.74
Self-Expressive Behavior	0.85	0.85	0.91	0.77
Subjective Norms	0.77	0.78	0.87	0.68

In terms of the discriminant validity, Table 4 shows that each AVE value is greater than the minimum and average variances extracted, and by applying the Fornell-Lacker criterion (Table 5), it reveals that all square roots of AVE values are larger than their respective inter-correlation coefficients (Alalwan et al., 2017). In addition, we also tested the discriminant validity using the HTMT criterion (Table 6), which showed that all of the HTMTs are below 0.90 (PLS-SEM, 2015).

Table 5. Fornell-Larcker Criterion

	1	2	3	4	5	6
Attitude (1)	0.85					
Environmental Knowledge (2)	0.38	0.78				
Perceived Behavioral Control (3)	0.51	0.45	0.8			
Purchase Intention (4)	0.57	0.66	0.63	0.86		
Self-Expressive benefit (5)	0.53	0.32	0.45	0.51	0.88	
Subjective Norms (6)	0.51	0.4	0.62	0.58	0.47	0.83

Table 6. HTMT Ratio

	1	2	3	4	5	6
Attitude (1)						
Environmental Knowledge (2)	0.50					
Perceived Behavioral Control (3)	0.66	0.65				
Purchase Intention (4)	0.70	0.88	0.82			
Self-Expressive benefit (5)	0.64	0.43	0.57	0.61		
Subjective Norms (6)	0.64	0.55	0.82	0.72	0.58	

Finally, Table 7 exhibits that all items load strongly to their respective constructs and confirm discriminant validity.

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Table 7. Cross Loadings

	Attitude	Environmental Knowledge	Perceived Behavioral Control	Purchase Intention	Self-Expressive Behavior	Subjective Norms
ATT1	**0.82**	0.31	0.41	0.49	0.44	0.44
ATT2	**0.88**	0.37	0.48	0.52	0.48	0.47
ATT3	**0.84**	0.27	0.40	0.44	0.44	0.37
EK1	0.3	**0.82**	0.42	0.54	0.23	0.30
EK2	0.27	**0.77**	0.33	0.49	0.27	0.32
EK3	0.31	**0.75**	0.31	0.52	0.27	0.31
PBC1	0.48	0.4	**0.83**	0.56	0.46	0.61
PBC2	0.35	0.34	**0.82**	0.47	0.31	0.49
PBC3	0.37	0.34	**0.74**	0.47	0.29	0.36
PI1	0.48	0.58	0.58	**0.87**	0.39	0.51
PI2	0.46	0.58	0.53	**0.88**	0.45	0.47
PI3	0.54	0.54	0.52	**0.83**	0.47	0.51
SEB1	0.48	0.29	0.47	0.45	**0.89**	0.45
SEB2	0.47	0.27	0.36	0.47	**0.87**	0.42
SEB3	0.47	0.30	0.37	0.42	**0.87**	0.38
SN1	0.35	0.30	0.43	0.40	0.31	**0.82**
SN2	0.47	0.32	0.55	4.48	0.41	**0.80**
SN3	0.42	0.35	0.53	0.52	0.43	**0.87**

4.4 Interpretation of Structural Model Results

The structured model results posit insights into the direct, mediated, and moderated relationships among self-expressive behavior, attitude, subjective norms, perceived behavioral control, environmental knowledge, and purchase intention. The authors summarize the results of hypothesis testing below in Table 8.

4.4.1 Direct Relationships

The findings indicate that ATT, SN, and PBC hold a positive and statistically significant relationship with purchase intention. The values of the standardized path coefficient of ATT ($\beta = 0.22$, $p < 0.001$), SN ($\beta = 0.16$, $p < 0.001$), and PBC ($\beta = 0.22$, $p < 0.001$) indicate that people

with positive attitude, strong social pressure, and high perceived control will be more likely to form intentions toward purchase behavior as H1 predicted.

Table 8. Path Analysis

Hyp	Structural Path	Beta	T values	P Values	Remarks
Direct Relationships					
H1	Attitude ⟶ Purchase Intention	0.22	5.09	0.00	Supported
H2	Subjective Norms ⟶ Purchase Intention	0.16	4.39	0.00	Supported
H3	Perceived Behavioral Control ⟶ Purchase Intention	0.22	4.79	0.00	Supported
H4	Self-Expressive ⟶ Attitude	0.53	14.75	0.00	Supported
Mediated Relationship					
H5	Self-Expressive ⟶ Attitude ⟶ Purchase Intention	0.12	4.53	0.00	Supported
Moderated Relationships					
H6	Attitude x Environmental Knowledge ⟶ Purchase Intention	0.06	1.21	0.23	Not Supported
H7	Subjective Norms x Environmental Knowledge ⟶ Purchase Intention	0.11	2.76	0.01	Supported
H8	Perceived Behavioral Control x Environmental Knowledge ⟶ Purchase Intention	0.01	0.14	0.89	Not Supported

Formal path assimilations are also presented in Figure 2. In addition, Self-Expressive Behavior (H4) significantly affects Attitude ($\beta = 0.53$, $p < 0.001$), meaning a customer involved in self-expressive behavior is more likely to form a favorable attitude concerning the purchase decision.

4.4.2 Mediated Relationship

The mediation analysis supports H5, showing that Self-Expressive Behavior indirectly influences Purchase Intention through Attitude ($\beta = 0.12$, $p < 0.001$). This result confirms that self-expressive behavior enhances attitudes, which in turn leads to stronger purchase intentions.

4.4.3 Moderated Relationships

Environmental Knowledge does not significantly moderate the influence of Attitude on Purchase Intention (H6) ($\beta = 0.06$, $p = 0.23$), so that Environmental Knowledge does not reinforce or attenuate the effect of Attitude on Purchase Intention. Likewise, Environmental Knowledge is not a significant moderator of the effect of Perceived Behavioral Control on Purchase Intention (H8) ($\beta = 0.01$, $p = 0.89$), indicating that perceived control over purchases does not vary with consumers' level of environmental knowledge. In contrast, the interaction between Subjective Norms and Environmental Knowledge (H7) is found to be significant ($\beta =$

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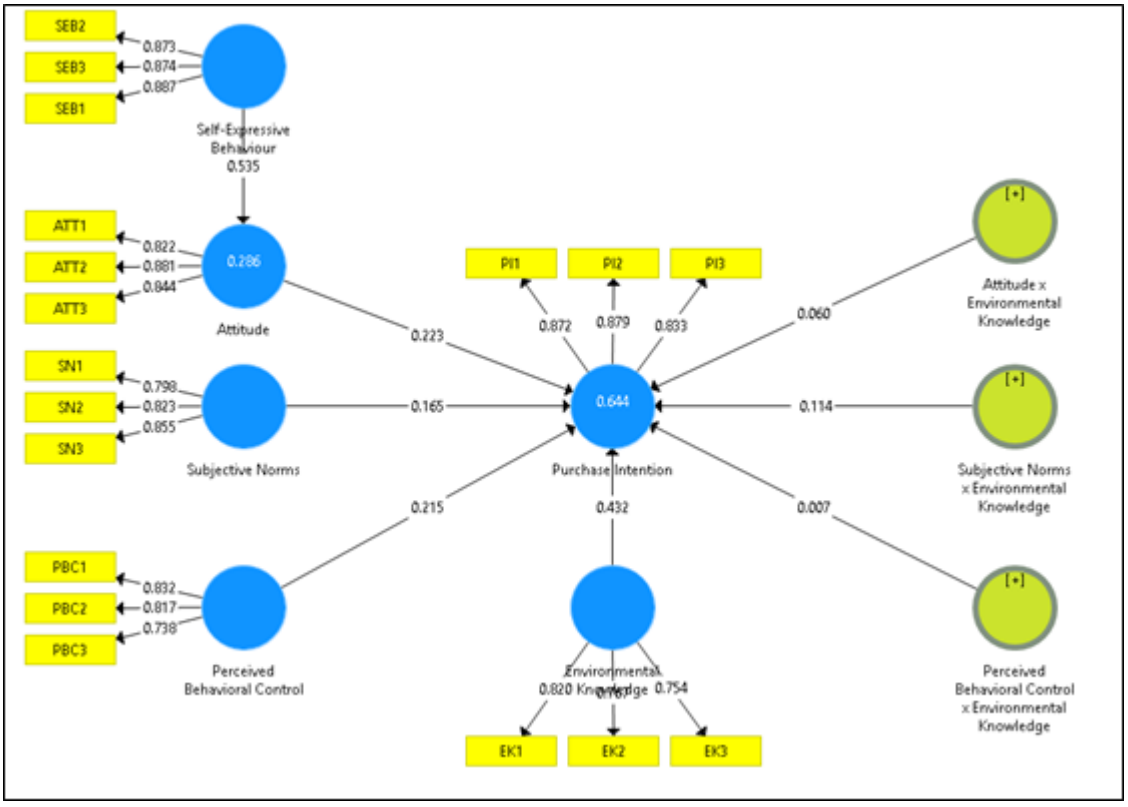
0.11, p = 0.01), indicating that high environmental knowledge reinforces the influence of subjective norms on purchase intention. It indicates that, for purchase intention, the influence of social norms is stronger among those who know about environmental issues. The non-significant moderating effects of environmental knowledge on the relationships between attitude, perceived behavioral control, and purchase intention suggest that these constructs may operate largely independently of consumers' environmental awareness. Attitude toward energy-efficient appliances is often shaped by personal evaluations, economic considerations, and habitual preferences, which may remain stable regardless of knowledge level. Similarly, perceived behavioral control reflects consumers' perceptions of affordability, availability, and access, factors that are not necessarily influenced by environmental information. These findings are consistent with previous studies reporting weak or insignificant moderation effects of environmental knowledge in green purchase contexts, suggesting that knowledge alone may be insufficient to strengthen internal drivers of behavior.

Figure 2. Structural Model



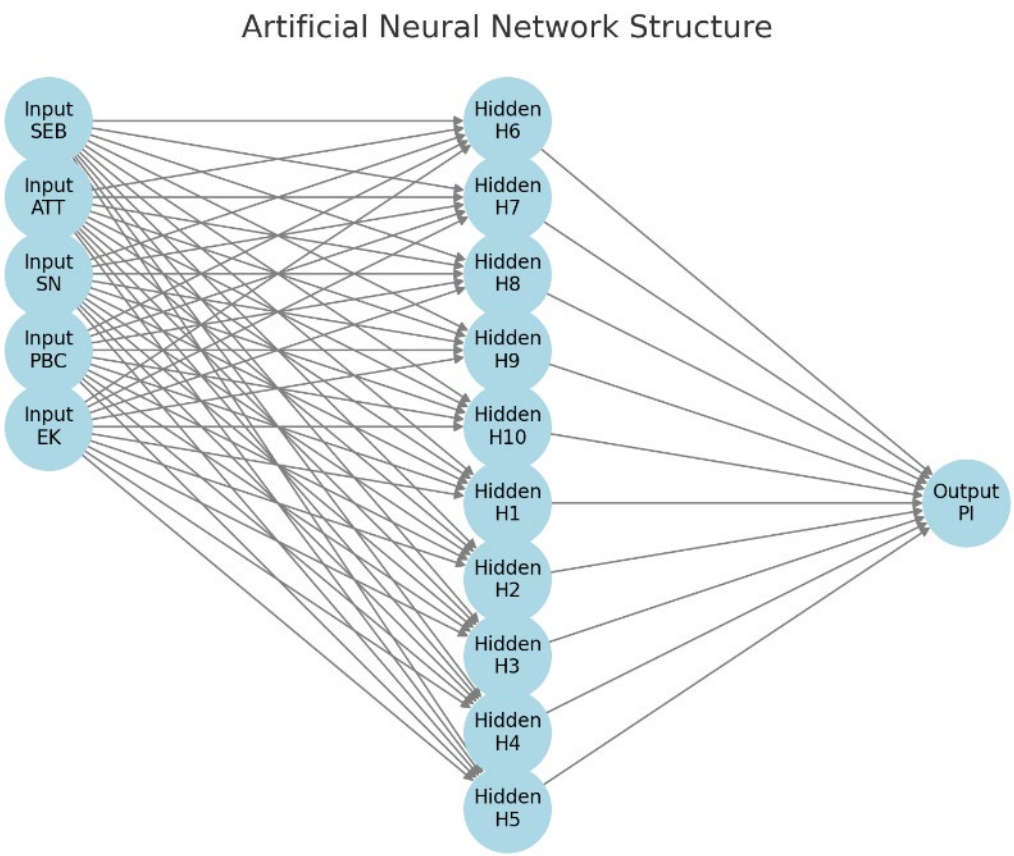
4.5 Artificial Neural Network (ANN) Analysis

In addition to a regression analysis and considering non-linear relationships between predictors of PI (Performance Indicator), this research uses an ANN model. The ANN method is based on previous research (Leong et al., 2019) and applies an MLP with a feed-forward back-propagation algorithm. This approach offers richer views of variable importance and predictive accuracy than classic regression models.

4.5.1 ANN Model Architecture and Training

The ANN model used in this work is a three-layer multilayer perceptron (MLP) that can model complex and nonlinear relationships between the independent variables and the dependent variable. Figure 3 provides the graphical depiction of the model. The input layer is composed of five neurons, which correspond to the interesting predictors (SEB, ATT, SN, PBC, and EK), as shown by the statistically highest significance in previous analyses (Leong et al., 2019). The hidden layer consists of ten neurons based on prior methodological recommendations in ANN applications within social science research (e.g., Haykin, 1999; Leong et al., 2019), as well as through iterative testing to balance model complexity and predictive accuracy while avoiding overfitting. by a single neuron of the output layer, which predicted the value of PI (Purchase Intention) as an exchangeable.

Figure 3. Artificial Neural Network



The model was compiled with the Adam optimizer at a learning rate of 0.001, and using Mean Squared Error (MSE) loss to minimize prediction errors. The network's training was stopped at 1,000 iterations to improve generalization and avoid overfitting, leading to an optimal solution. This methodological procedure is consistent with the recommended neural network applications in social science research (Haykin, 1999), and it offers a strong procedure to test the prediction potential of central behavioral determinants.

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4.5.2 Model Performance Evaluation

To evaluate the predictive power of the ANN model, it was validated by using different train test split ratios for generalization performance analysis. This methodology was adopted based on similar studies that also compare the performance of machine learning models using various data partition approaches (Leong et al., 2019). The metrics of performance are: Mean Squared Error (MSE), Root Mean Squared Error (RMSE), and R^2 Score (Table 9).

Table 9. ANN Performance Across Different Training-Testing Splits

Train-Test Split	MSE	RMSE	R^2
50-50	0.2998	0.5475	0.423
60-40	0.3221	0.5676	0.377
70-30	0.2783	0.5275	0.451
80-20	0.2953	0.5434	0.450
90-10	0.3037	0.5511	0.467

The best predictive performance was revealed with the 70–30 split; the lowest MSE (0.2783) and highest R^2 (0.451). This is consistent with the results reported from ANN-based prediction modeling, as moderate training proportions usually contribute to better generalization (Zhang et al., 2019).

4.5.3 Sensitivity Analysis of Predictors

A sensitivity analysis was performed using this model to assess the relative impacts of each predictor on prediction by perturbing input variables and observing changes in output predictions (Table 10). This is in line with the previous ANN ranking of variable methodologies (Olden & Jackson, 2002).

Table 10. Sensitivity Analysis of Predictors (ANN Rankings)

Feature	Sensitivity	Normalized Sensitivity (%)
ATT (Attitude)	0.00693	100.00
SN (Subjective Norms)	0.00507	73.20
SEB (Self-Expressive benefit)	0.00507	73.14
PBC (Perceived Behavioral Control)	0.00245	35.34
EK (Environmental Knowledge)	0.00131	18.91

Results indicate that ATT (Attitude) is the most relevant of the PI system, before SN (Subjective Norms), but after SEB (Self-Expressive Benefit). A lower effect of EK (Environmental Knowledge) shows that environmental issues have less influence than economic or behavioral factors in comparison.

5. Discussion

The objective of the study was also to integrate additional cognitive antecedents (like Self-expressive benefits and environmental knowledge) in addition to TPB variables. The findings

indicated that the developed model is generally acceptable and suitable for understanding product purchases of 'Energy Efficient Appliances' as extended TPBs can predict purchasing intention.

The findings reveal that Attitude significantly has a positive effect on the purchasing intention of energy efficiency appliances. It is indicated that the more favorable households feel energy-saving appliances, the likelihood of making such a purchase becomes higher, and this confirms results obtained in (Nguyen & Nguyen-Ngoc, 2025; Basiru et al., 2024). This study also affirmed the proposition that customers' subjective norms serve the intention of buying energy-saving home appliances. The subjective norms were a meaningful predictor of purchase intention. It is concluded that consumers are influenced by others´ values when buying energy-efficient home appliances. This is in line with results from existing studies, which demonstrated that subjective norms stimulate environmental behaviors and purchasing of green products (Nguyen & Nguyen-Ngoc, 2025; Basiru et al., 2024).

The findings showcase that the PBS factor of PBC positively and significantly affects purchase intention of EEHAs. The PBC strongly influences intention to purchase as an indicator of the degree to which a person feels that an action is easy or difficult to perform. When consumers have enough money, access to products and information for evaluating them in the case of buying energy-saving appliances, they have a higher intention to purchase. On the other hand, if barriers are feared (e.g., high price or low availability, and lack of knowledge), then intention to purchase is reduced. PBC not only directly affects purchase intention but can also function as a moderator that reinforces or weakens other variables, attitude, and subjective norms in this case.

This corresponds to results from Myanmar, Kashmir, and Vietnam, in which Perceived Behavioral Control influenced purchase intention (Nguyen & Nguyen-Ngoc, 2025; Basiru et al., 2024). Self-Expressive Behavior has a material impact on attitude by enabling customers to bring their purchase in harmony with self-concept, values, and social image. Once people come to view purchasing energy-efficient appliances as consistent with their self-concept (e.g., environmentally responsible, modern, socially aware), they develop a more favorable evaluation of and attitude toward such products. This association will elevate emotional responses and reinforce the preference for green alternatives, subsequently facilitating acceptance of energy-efficient products. Hence, self-expressive benefits act as a psychological motivator, influencing consumer attitudes and supporting sustainable consumption behavior. This result concurs with those of others that self-expressive benefit influenced the purchase intention (e.g., Liao et al. 2020).

The mediation analysis provides evidence that self-expressive benefits will indirectly affect purchase intention via attitude. This result suggests that associating energy-efficient appliances with self-expression in terms of the consumers' personal values or social identity leads to a more positive attitude toward these products. This positive attitude, in its turn, reinforces the intention to buy from these people. This finding underscores the importance of attitude as a psychological conduit that converts self-expressive motives to specific purchase decisions. Similar results are in line with the previous studies (Boobalan et al. 2021).

The results of this study reveal that environmental knowledge does not significantly moderate the relationship between attitude and purchase intention toward energy-efficient home appliances. This suggests that although consumers may possess knowledge about environmental issues, such knowledge does not necessarily strengthen the influence of their attitudes on purchasing decisions. In other words, consumers who already hold favorable attitudes toward energy-efficient appliances may base their intentions primarily on perceived product benefits such as cost savings, efficiency, and long-term economic value rather than on their environmental awareness. Prior research has shown that consumers frequently evaluate

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green technologies based on utilitarian and economic benefits, which often outweigh purely environmental motivations in shaping purchase intentions (Lin & Dong, 2023; Asif et al., 2023).

This finding aligns with earlier research indicating that environmental knowledge does not always reinforce the effect of pro-environmental attitudes on behavioral intentions. For example, Li et al. (2021) reported that environmental knowledge failed to significantly moderate the relationship between attitude and purchase intention for energy-efficient appliances in China. Similarly, Hamzah and Tanwir (2021) found that environmental knowledge did not strengthen the impact of pro-environmental attitudes on consumers' purchase intentions in the context of hybrid vehicles. Additional studies also highlight that although environmental knowledge increases awareness, it may not directly translate into stronger purchase intentions without supportive motivational or contextual factors (Rehman et al., 2024; Anwar et al., 2024).

These results also complement more recent studies highlighting the dominant role of psychological and behavioral determinants —particularly attitude— in shaping sustainable consumption decisions (Basiru et al., 2024; Nguyen & Nguyen-Ngoc, 2025). Empirical evidence further suggests that attitudes toward green products are often formed through perceived value, trust, and product benefits rather than solely through environmental awareness (Lin & Dong, 2023; Tanveer et al., 2024). Taken together, these findings suggest that while environmental knowledge contributes to general awareness, it may not substantially intensify the attitudinal influence on consumers' purchase intentions.

Similarly, the findings demonstrate that environmental knowledge does not significantly moderate the relationship between perceived behavioral control and purchase intention. This implies that consumers' perceived ability to purchase energy-efficient appliances—such as affordability, accessibility, and availability of products—remains a stronger determinant of purchase intention than their environmental awareness. Even consumers with high environmental knowledge may not exhibit stronger purchasing intentions if they perceive financial or practical barriers associated with energy-efficient appliances. Previous studies examining energy-efficient appliance adoption have also emphasized that perceived behavioral control and situational constraints significantly influence consumers' purchasing decisions (Mohamed et al., 2025; Lin & Dong, 2023).

This result is consistent with prior research suggesting that structural and situational constraints often limit the translation of environmental awareness into actual purchase intentions. For instance, Hamzah and Tanwir (2021) also reported a non-significant moderating effect of environmental knowledge on the relationship between perceived behavioral control and pro-environmental purchase intentions. However, this finding contrasts with studies that suggest environmental knowledge can reinforce sustainable consumption behavior by enabling consumers to better evaluate environmental benefits and product attributes (Wang, Sun, et al., 2019; Jia et al., 2024). The divergence between these results indicates that the influence of environmental knowledge may be context-dependent and varies across product categories and cultural settings. Recent research also indicates that contextual factors such as environmental concern, social influence, and trust can significantly influence sustainable consumption behaviors alongside traditional TPB variables (Khan & Qureshi, 2025; Tanveer et al., 2024). Therefore, in the context of energy-efficient home appliances, economic and practical considerations appear to outweigh informational factors in shaping consumers' purchasing decisions.

Overall, the non-significant moderating role of environmental knowledge suggests that knowledge alone may not be sufficient to strengthen the psychological mechanisms that drive sustainable purchasing behavior. While environmental knowledge increases awareness of environmental issues, it does not necessarily translate into stronger behavioral intentions

unless it is accompanied by favorable attitudes, perceived benefits, and enabling conditions. Recent studies emphasize that consumers' green purchasing decisions are often influenced more strongly by perceived economic value, social influence, and product accessibility than by environmental awareness alone (Anwar et al., 2024; Tanveer et al., 2024; Lin & Dong, 2023).

Therefore, the findings of this study highlight the importance of complementing knowledge-based interventions with strategies that enhance positive attitudes and reduce perceived barriers to purchasing energy-efficient appliances. From a policy and marketing perspective, this implies that awareness campaigns should be integrated with economic incentives, clear product information, and improved accessibility to encourage the adoption of energy-efficient technologies. Such integrated approaches may be more effective in translating environmental awareness into actual purchase intentions and sustainable consumption behavior.

6. Theoretical Contribution

This study has several implications for the existing body of literature. First, to the best of the researchers' knowledge, this is one of the first studies explaining purchasing intention for residential energy-efficient appliances among Saudi Arabian consumers. Saudi Arabia is categorized as a developing country, and the income level is high, but temperature increases lead to high electricity demand. Second, this research expanded TPB by incorporating Self-expressive benefits and environmental knowledge to measure the intention of household energy-efficient appliance purchase. Previous research has further expanded TPB with other variables, namely Self-expressive benefits (Bhutto et al. 2022), and attitude is insignificantly affected by self-expressive. The current study also shows that attitude is not a significant mediator in the self-expressive benefit and purchase intention relationship, so further investigation is required to establish the results. Environmental knowledge was the second variable (Li et al. 2021); however, it did not pay attention to the tendency effect among subjective norms and perceived behavior control on purchasing intention of energy-efficient appliances. Lastly, as far as the study specific to purchasing intention of energy efficiency appliances is concerned, this research is among a handful of marketing studies that merged both PLS-SEM and ANN techniques.

7. Implications (managerial and Policy)

To a certain extent, the findings of this study contribute to academic research and provide significant implications for the state and manufacturers of EEAs. As attitude, subjective norm, and perceived behavioral control have a positive effect on purchasing intentions of Saudi consumers, the government should encourage producers, importers, and sellers of appliances that equally promote energy efficiency products positively. The motivations will also increase the purchasing intention level of Saudi consumers toward energy efficiency appliances, such as the refrigerator, which has low efficiency to save electric power compared to traditional products that consume a high amount of energy and pay huge amounts each month.

Social media communications, such as Facebook, LinkedIn, TikTok, X, and Instagram ads, motivate consumers to exchange old home appliances for energy-efficient ones while also controlling the price level of these devices and increasing environmental awareness towards climate degradation. Domestic appliance retailers may provide monetary incentives (for instance, cashback or discounts) when buying energy-efficient appliances. On the other hand, these products should reach markets near consumers to reduce their access time and cost to

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make an effort to find and acquire them. The self-expressive benefits also have an impact on consumer attitudes to purchase energy-efficient appliances through identity, ascription, and emotional attachment, resulting in the intention to buy them.

For diversified insights, qualitative methodologies can be explored, for they can probe into the purchase intention of consumers on energy-efficient household appliances and reflect a more profound psychological status of consumers. A model that can be used to examine the moderating effects of consumer characteristics such as self-concept, recycling, and cultural knowledge.

8. Conclusions and Limitations

This study investigates the determinants of buying intention of EEHAs in the Saudi Arabian market. It validates the variables of attitude, subjective norms, and perceived behavioral control, which influence consumers' intention to buy energy-efficient home appliances. Moreover, the results confirm the impact of self-expressive benefits on attitudes towards purchasing energy-efficient home appliances. It has also been found that environmental knowledge moderates the relationship between subjective norms and PEPU for EEHA consumers. Finally, the findings reveal that the attitude mediates between self-expressive benefits and the buying intention of EEHA items.

The purchase intention of EEHAs has been studied in this research. The topic may also be expanded to repurchase intention in the future to see how consumers are retained. In fact, we employed behavioral intentions to purchase energy-efficient appliances. Further research may include actual behavior, which would yield information on the extent to which intention materializes in terms of action.

Despite its contributions, this study has several limitations that should be acknowledged. First, the sample size, while adequate for PLS-SEM analysis, was obtained using a non-probability purposive sampling technique, which may limit the generalizability of the findings. Additionally, the sample was characterized by a relatively high educational level, which may not fully represent the broader Saudi population. Second, the study focused on respondents from a single geographic context within Saudi Arabia, which may restrict the applicability of the results to other regions or countries. Future research should consider employing probability-based sampling methods, larger and more diverse samples, and cross-regional or cross-cultural comparisons to enhance external validity.

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Authors' contributions

All authors contributed equally to the Conceptualization, Methodology, Software, Data acquisition, Analysis and interpretation, Writing- Preparation of the draft, Writing-Revision & Editing. All authors read and agree with the published version of the manuscript.

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