



EXPLORING GREEN PURCHASE BEHAVIOR THROUGH THE LENS OF EXTENDED TPB: THE ROLE OF GREEN PURCHASE INTENTION AND GREEN BRAND KNOWLEDGE

*Imran Zafar Butt¹, Dr Sajjad Ahmad²

¹ Business & Management Sciences, Minhaj University Lahore, Punjab, Pakistan.

² Associate Professor, Business & Management Sciences, Minhaj University Lahore, Punjab, Pakistan.



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ABSTRACT

The factors influencing Green Purchase Behavior (GPB) in the context of solar technology adoption are examined in this study using the extended Theory of Planned Behavior (TPB). Through the mediating function of Green Purchase Intention (GPI), the model examines the impact of Environmental Factors (EF), Green Attitude (GA), Subjective Norms (SN), and Perceived Behavioral Control (PBC) on GPB. Green Brand Knowledge (GBK) is investigated as a moderator. Using a snowball sampling strategy, data was gathered from 380 commercial solar technology customers in Punjab, Pakistan, and PLS-SEM in SmartPLS was used for analysis. The findings show that whereas GPI considerably increases GPB, EF, GA, SN, and PBC positively and significantly affect GPI. Additionally, GPI mediates the associations between GPB and all antecedent factors, underscoring its crucial role in converting consumers' attitudes and perceptions of the environment into actual purchasing behavior. In terms of moderation, GBK considerably increases the effects of EF, GA, SN and PBC on GPI. Hence all direct relations, mediated relations and moderation-based relations of current study are found significant. The results validate the extended TPB framework and offer insightful information about encouraging green purchasing practices among commercial solar system customers.

*Corresponding Author's Email: 2019s-mulmpl-mgt-008@mul.edu.pk

INTRODUCTION

During the time period of 1980s 2°C increase in temperature was observed in several European countries throughout the months of June, July, and August; this local warming is nearly thrise more than the global warming that has taken place during that time (Schumacher et al., 2024). These verdicts highlight the considerable penalties of weather change in South Australia, which are resulted by a decrease in cold extremes and hot extremes (Ferrelli, Pontrelli Albisetti, Brendel, Casoni, & Hesp, 2024; Gampe et al., 2024). These 1.5°C to 2°C increase in extream weather reflects more significant increament in temperature in near future (Wei et al., 2024). In such circumstances, it is essencial to take proactive actions in order to reduce the expented bad impact of weather change on health (Bhattacharya et al., 2024). Firms of international scale have started working on renewable resources by avoiding the use of fossil fuels for electricity production (Maji, Bashir, Irwin, Shenoy, & Sitaraman, 2024).

Pakistan is one of the countries most affected by climate change (Adnan et al., 2024). Pakistan is the world's second most contaminated country reported by world air quality in 2023. All of these elements highlight the persistent need for both local and global mitigating measures (Iqbal, 2024). We need to satisfy the need of electricity without polluting the anvironment (Doğan, 2024). In Portgal the major residents of central area

were most affected (Moura, Fonseca, Cunha, & Morais, 2024). It is recommended that state should focus on production of sustainable sources of electricity production (Sarwar Khan, Hussain, Ali, & Ali). Pakistanies have to pay major portion of their income to pay electricity bills (Hussain et al., 2024). There is huge shortage of electricity in Pakistan (Amin et al., 2022). World has moved towards the renewable energy sources (Lawani, 2024; Oguanobi & Joel, 2024).

Efforts should be done to reduce carbon emissions and promote energy independence by using solar photovoltaics (Rasheed et al., 2024). Customers who are highly concerned about the environment feel proud when they think about sustainable consumption (Maduku, 2024). It is crucial to support the sharing of EK within communities for environmental awareness (Putri & Hayu, 2024). Attaining and retaining the customers is the main focus of marketing experts (Toha & Supriyanto, 2023). Green items should be produced at large scale if we want to increase green users (Nazmi & Kurniawati).

Solar energy is the best among all three available resources wind energy, bioenergy and solar energy (Rusilowati, Ngemba, Anugrah, Fitriani, & Astuti, 2024). China has to survive on coal resources for generation of electricity (Zaghdoudi, Tissaoui, Hakimi, & Ben Amor, 2024). In future more technical firms will focus renewable resources to eliminate environmental issues and produce sustainable electricity (Gajdzik, Wolniak, Nagaj, Żuromskaitė-Nagaj, & Grebski, 2024; Nazarov, Sulimin, & Shvedov, 2024). As for as solar energy is concerned location of Pakistan is ideal for sunlight (Muhammadi et al., 2024). Energy resources in Pakistan are reduced due to increase of population (Khan et al., 2024). It is core components of Sustainable Development Goals (SDGs). Pakistan has the potential to produce up to 100,000 MW of electricity from sunlight. It is best alternate of electricity production as replacement of thermal power (Muhammadi et al., 2024). Since the rates of conventional energy production resources are too high and rates of solar energy equipment have been reduced so it is golden opportunity to install solar energy in Pakistan (M. Ahmed et al., 2024; Arshad, 2024).

THEORETICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

Underpinning Theory: Extended TPB

The current study's underlying idea is Icek Ajzen's 1991 TPB. The three primary independent variables of TPB are term GA, SNs, and PBC. These factors actually have an impact on behavioral intentions.

This theory built upon the previous Theory of Reasoned Action (TRA). This theory could be expanded to include EK and EC as dimensions of EF. One of the most comprehensive aspects made feasible by this expanded or improved TPB framework is environmental elements. It is therefore referred to as expanded TPB (La Barbera & Ajzen, 2024).

A person's thoughts and expectations about the results of a specific behavior form the basis of their attitude. The SNs are linked to the perceived social pressure to engage in or refrain from an activity from friends, family, or society. The perceived ease or difficulty of an action is addressed by the PBC (Núñez-Naranjo, Morales-Urrutia, Mantilla-Falcón, Ibarra-Torres, & Córdova, 2026). In order to better impact behaviors and sustainable practices, the Extended TPB incorporates variables such as environmental issues (Tinh, My, Minh, Hung, & Phan, 2026). Term GT acts as a mediator when GA, PBC, SNs, and GPI collaborate to buy green products. Higher GT consumers choose eco-friendly products more wisely (Siyal, Ahmed, Ahmad, Khan, & Xin, 2021).

Explanation of Variables

Green Purchase Behavior

In the recent times GPB has gained much importance (Ng, Cheung, Lit, Wan, & Choy, 2024). Term GPB is considered as the bridge between the GPI and the actual purchase. Hence GPB is considered as more crucial stage before the actual purchase (Hong, Rasheed, Sigala, & Ahmad, 2024). It has become too difficult to attain and retain the customers on continuous basis more specifically for the small businesses due to limited resources and competition (Abid, Ceci, & Aftab, 2024). Complete dependence on the new client is the weak point for SMEs (Fisher-Robinson, 2024). Peer pressure in the form of SN have a big impact on GPB. People are more inclined to adopt ecologically beneficial practices when they observe their peers, colleagues and family members doing so (Arwani, Maskudi, Pratiwi, & Malik, 2025; Liaquat, Iqbal, Munir, & Waheed, 2024; Setyarko, Noermijati, Rahayu, & Sudjatno, 2024).

Environmental Factors

The knowledge about the ecological problems, clean products and impact of pollution free products on the environment is termed as EK. It guides the consumers towards ecological and sustainable

products (Mabkhot, 2024). Knowledge about the ecological issues and concerns is a leading process of in mental makeup regarding green purchasing decisions (P. Li, Lin, & Chen, 2024). Two main component that significantly impact GPB are EK and EC (de Oliveira Lima et al., 2024). The intensity of EK and EC guide the consumers to search and purchase the green products (Pathange et al., 2024; Pontes, Naranjo-Zolotov, & Painho, 2024; Shafiq, Khan, & Tahir, 2024). Green consumers always seek for the green products or environment friendly recycled products (Isbahi, Pertiwi, & Purwanto, 2024). Customers search the products with less environmental impact and made up of eco-friendly materials (Mbokane & Modley, 2024).

Green Attitude

Green Attitude possesses both positive and negative inclination towards the green purchase behavior. Converting PA towards GPI and GPI into GPB of green products is a big problem of developing countries (Corboş, Bunea, Triculescu, & Mişu, 2024; Palomino Rivera & Barcellos-Paula, 2024). Strong environmental attitudes correlate with a greater intention to purchase green products (Gading, Kuswati, Achmad, & Lestari, 2024). The term PBC have the ability to directly influence GPB or by mediation of GPI (Liu & Madni, 2024). It is concluded that EF, SN, GA and PBC impact GPI and GPB. Personal consumer belief to perform an action is referred to as PBC (Mutmainah & Wahidhani, 2024). Clients are worried about the eco-friendly problems such as macroclimate modification, contamination, and reprocessing of the products (Upadhyay, 2024).

Subjective Norms

The perceived social pressures by friends, family members, coworkers, or wider societal expectations are termed as SN (Tiara & Religia, 2025). In other words the social ideas and expectations that are influenced by an individual's immediate surroundings, such as the views and actions of friends, family, coworkers, and other significant individuals, are known as SN (N. Le, Vo, Bui, & Vu, 2025). Such norms are the cultural and societal expectations that shape a person's conduct (Ayieko et al., 2024). It can be decomposed into descriptive norm (DN) and injunctive norm (IN) (Botetzagias, Grigoraki, & Kokkoris, 2024). Social values in the form of SN have a big impact on customers' GPI (Fortuna, Wilson, Metta, Chandra, & Darmawan, 2025). It has been observed in multiple studies that

SN play a significant role in directing intents (Ka & Nguyen, 2025; Y. Li & Shan, 2025). Therefore, SN play a significant role in influencing intentions (Dahhan & Arenkov, 2025).

Perceived Behavioral Control

A core component of TPB theory is PBC which indeed plays a significant role in influencing consumers' online purchasing behavior. It refers to the perception of one's ability to perform a particular behavior (Acharya, Poudel, & Simkhada, 2024). Ajzen states that PBC is indeed based on two key components: self-efficacy and controllability (Ajzen, 2002). Self-efficacy is a person's confidence in their capacity to carry out a certain action or task. Whereas controllability describes how a person views outside influences that either help or hinder them from engaging in a behavior (Naybezade et al., 2025). It may influence behavior directly or by triggering the behavior through intention (Liu & Madni, 2024). When examining drivers' behavior, PBC is essential because it measures their confidence in their capacity to carry out required driving actions and make safe choices (Kotyza et al., 2024). The degree to which people think they have control over how an action is performed is termed as PBC (Omulo, Daum, Köller, & Birner, 2024). Both GPI and GPB are greatly enhanced by PBC, especially when customers believe they have control over the data and resources required to make sustainable decisions (Gao, Zhao, Ma, & Li, 2023). PBC is the consumer's assessment of how simple or complex it is to buy green products (Chao & Yu, 2024).

Green Purchase Intention

Most central component of TPB is GPI. It reflects the degree to which consumers are willing to prioritize sustainability in their purchasing choices (BV & Rajendran, 2024). Intention of green purchasing may be decomposed into engagement, usefulness, and reliability (Poon, Kunchambo, & Koay, 2024). Strong purchase intentions are a good predictor of actual buying behavior (Liaquat et al., 2024). Consumers' level of involvement in purchasing decisions can significantly affect their behavior, especially when it comes to pro-environmental activities like buying green products (Liang, 2024). The intention reflects their readiness to make a purchase that aligns with their environmental values (Ahmed, Štreimikienė, Sulaiman, Asim, & Štreimikis, 2024). Study advocates that EC, EK, GA, SN and PBC have positive impact on GPI and GPB (Pontes et al., 2024).

Green Brand Knowledge

Green Brand Awareness (GBA) and Green Brand Image (GBI) make up Green Brand Knowledge (GBK). While GBI shows consumers' overall opinion of a brand's environmental performance and sincerity, GBA shows how well people perceive and comprehend a brand's eco-friendly qualities. Both are essential for shaping customer behavior and market positioning in the green industry (Gautam & Pokhrel, 2023). Knowledge of green brands reflects how well consumers understand and accept a brand's eco-friendly attributes. Higher awareness makes green products more noticeable, enabling conscientious consumers to identify and choose them more easily, increasing their preference over less recognized competitors (Mitariyani, Gama, & Widnyani, 2024).

Hypotheses Development

Environmental Factors and Green Purchase Intention

Environmental Knowledge describes the knowledge an individual has regarding the environment, climate change and ecological aspects whereas EC indicates the concern one has about the ecological aspects. Both EK and EC jointly describe EF and EF significantly influence GPI and GPB (Saari, Damberg, Frömling, & Ringle, 2021). Term EC significantly and favorably influences GPI, indicating that those who care more about the environment are more likely to buy green food products (Cui, Li, & Wang, 2024; De Canio, Martinelli, & Endrighi, 2021). In generic EK provides basic information about the environmental issues and their respective solutions which influence the PI. The EK and EC as two basic dimensions of EF have massive influence on GPI and GPB (Marfo et al., 2024). On the basis of above discussion, we can hypothesis that:

H₁: There is direct effect of EF on GPI

Green Attitude and Green Purchase Intention

Students of Chile used an education-based ap in which it was observed that GA, SN and PBC influenced GPI using the TPB as a framework (Meliniasari & Mas'od, 2024). Another study demonstrate that GA affects GPI (Nurfikri, Kesa, Wu, Roselina, & Hidayat, 2024; Palomino Rivera & Barcellos-Paula, 2024) under TPB theory. Term GA affects GPI and GPB (Rama & Susanto, 2024). Another study advocate that GA influences the GPI which ultimately impacts GPB (Kwon & Ahn, 2021; Palomino Rivera & Barcellos-Paula, 2024). We may purpose that green attitude has a significant impact on GPI (Sihombing et al., 2024). Attitude is a crucial

component influencing GPI and decision-making (Jánská, Žambochová, & Kita, 2023). Attitude is the best predictor of GPI and GPB (Ogiemwonyi, 2021; Quadree & Pahari, 2022). On the basis of above discussion, we can hypothesis that:

H₂: There is direct effect of GA on GPI

Subjective Norms and Green Purchase Intention

Individual attitudes and perceived control over technology use influence behavioral intentions (Koufie, Tetteh, Kwarteng, & Fosu, 2024). Someone whose family and friends expect them to drive a personal vehicle or see driving as the usual, this social support can strengthen the intention to use public transportation (Bhagat-Conway et al., 2024). A study shows that there is a gap in the way green actions are objectively measured (Randall et al., 2024). Marketers better understand how to deal with this generation by utilizing peer interactions and social media networks (T.-M. H. Le & Ngoc, 2024). Family members, society or people working with an individual in the form of SN can influence both GPI and GPB. Research indicates that GA, PBC and SN influence GPI and GPB (Hayu, Hidayat, Anggrawati, & Wiardi, 2023). On the basis of above discussion, we can hypothesis that:

H₃: There is direct effect of SN on GPI

Perceived Behavioral Control and Green Purchase Intention

The TPB framework shows how these social and psychological elements interact together to influence behavioral intention (Barry, Haque, & Jan, 2024). Hotel visitors' PBC increases and their intention to return is positively impacted if they are clear in their believes. These factors work together to affect purchase intention (Han & Kim, 2010; Makamba, 2024). The TPB framework is somewhat especially useful for figuring out what Muslim consumers want to buy (Maduku & Mbeya, 2024). Research has concluded PBC significantly predict the intention (Cheung & Chan, 2000). Students' confidence and willingness to participate in physical activity are greatly influenced by how easy or difficult they perceive it (Su, Wan, Zhang, Teng, & Chan, 2024). On the basis of above discussion, we can hypothesis that: **H₄: There is direct effect of PBC on GPI**

Perceived Behavioral Control and Green Purchase Behavior

Perceived behavioral control positively impact purchase behavior through mediation of PI but it also directly effects GPB (Xu et al., 2022). Attitude and

PBC effect GPB through mediation of intention but PBC directly effects the GPB (Askadilla & Krisjanti, 2017; Zdonek, Hysa, & Zdonek, 2024). According to another study PBC greatly influence GPB. Term PBC refers to the perception of one's ability to perform a particular behavior (Acharya et al., 2024). It has been observed that GPI and GPB are both greatly influenced by PBC (Gao et al., 2023). Person's perceived ability and competence to successfully do the necessary tasks is termed as PBC (Hasesda, Yulianto, & Fahrudi, 2024). According to a study GPB and GPI are significantly influenced by PBC (Afridi, Khan, Haider, Shahjehan, & Afsar, 2021; Badawi et al., 2024). Based on the above discussion, we may hypothesis that:

H₅: There is direct effect of PBC on GPB

Green Purchase Intention and Green Purchase Behavior

A study conducted regarding Green Purchase Behavior (GPB) in Indonesia examined that GPI significantly impacted the GPB of green products (Vironika & Maulida, 2025). Another study conducted in Greece reflected that there is a substantial, positive, and statistically significant direct relationship between Green Purchase Intention (GPI) and Green Purchase Behavior (GPB) ($\beta = 0.714$, $t = 23.673$, $p < 0.001$). A significant increase in customers' actual green purchasing behavior is linked to an increase in their desire to make green purchases, according to the standardized correlation of 0.714. Based on the above discussion, we may hypothesis that:

H₆: There is direct effect of GPI on GPB

Mediating Role of GPI

An investigation of the association between EK and EC on GPI was carried out in Malaysia. Research has demonstrated that environmental elements have a favorable and substantial effect on GPI (Marhadi, Sudibyo, Priatmoko, & Suyastri, 2024). This Malaysian study lends credence to the idea that EK and EC both significantly effect GPI. By identifying specific motivators and obstacles to buying eco-labeled electronics, support both environmental objectives and the financial sustainability of sustainable products (Yan, Jin, & Yew, 2024).

On the basis of above observations, we propose the following hypothesis:

H_{1a}: GPI mediates the relationship between EF and GPB

A person's behavior to buy green products will rise in direct proportion to their positive attitude toward them (Vania & Ruslim, 2023). Attitude plays vital role in developing GPI and GPB (Imiru, 2023). As consumers grow more environmentally conscious, their positive perceptions of green items influence both their intentions to buy and their actual purchasing behavior. On the basis of above evidences, we may hypothesis that:

H_{2a}: GPI mediates the relationship between GA and GPB

A research advocates that SNs has influence on GPI (Chin, Mustafa, & Nungsari, 2024). Many studies recommend that SN is a strong predictor of GPI and GPB (Moazzam, Ahmad, Hussain, & Akram, 2023). On the basis of the above studies we formulate the following hypothesis: -

H_{3a}: GPI mediates the relationship between SN and GPB

According to a study GPI is effected by GA, SN, PBC, and EF (Panda, Singhal, Jena, & Tripathy, 2024). The GPI has positive impact on GPB which reflects GPI positively mediate the relationship between PBC and GPB (Jana, Shandilya, & Srivastava, 2024). According to a study in Jakarta Indonesia GPI significantly mediate the relationship between PBC and GPB (Yusuf, 2021). Hence GPI is a major mediating factor in the relationship of PBC and GPB. On the basis of above discussion, the following hypothesis is proposed: -

H_{4a}: GPI mediates the relationship between PBC and GPB

Moderation Role of Green Brand Knowledge

Good opinions of green brands strengthen GA, increase brand awareness of GBK (Gautam & Pokhrel, 2023). Environmentally conscious consumers are more likely to buy green products, especially when they have strong GBK. GBK boosts confidence and motivation by helping consumers identify brands that share their values. (Park, Bitaab, Lee, & Back, 2024). This study examines how GBK influences green brand positioning, GA, EC, and GPI among Pakistani consumers. It explores how GBK affects the relationship between these factors, aiming to understand its role in shaping eco-friendly purchasing decisions in Pakistan's market (Siyal et al., 2021). On the basis of above discussion, we can hypothesis that:

H_{1b}: GBK moderates the relationship between EF and GPI

The verdicts specify that GBK significantly moderates the links between SN, GA, and GPI. These factors have a stronger influence on purchase intentions among consumers with higher knowledge of products (Kittirattanadetch & Nurittamont, 2024; Wang, Pacho, Liu, & Kajungiro, 2019). Although perceived behavioral control hurdles like high pricing and restricted availability may mitigate this effect, GBK increases GPI, especially when SN and GA are strong (Shirai, 2025). The association between green brand positioning (GBP), GA, EC, and GPI is moderated by GBK, which represents customers' comprehension of eco-friendly brands (Siyal et al., 2021). Customers who are more concerned about the environment are more likely to buy eco-friendly products, and this trend is reinforced by GBK.

H_{2b}: GBK moderates the relationship between GA and GPI

H_{3b}: GBK moderates the relationship between SN and GPI

H_{4b}: GBK moderates the relationship between PBC and GPI

Conceptual Framework

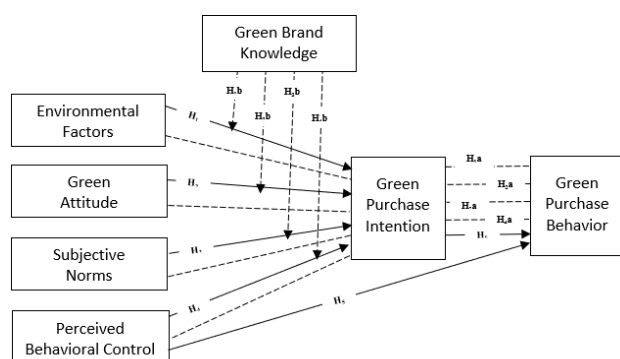


Figure 1: Conceptual framework

Figure 1 illustrates the conceptual framework of current study that reflects impact of EF, GA, SN, PBC on GPB with mediation role of GPI and moderation role of GBK. It also includes the identification of hypotheses of direct, mediation and moderation-based relations.

METHODOLOGY

To investigate the factors that influence GPB toward solar technology, the current study uses a main, quantitative research approach. In addition to one dependent variable GPB, the conceptual framework includes four independent variables; EF, GA, SN and PBC. Furthermore, GBK is proposed as a moderating variable and GPI as a mediating construct. The study's target population is Punjab, Pakistan's commercial solar technology adopters,

who make up a sizeable portion of the country's renewable energy consumers. A standardized survey instrument was used to gather data, and a snowball sampling strategy was used to guarantee that a wide range of respondents from the commercial sector could be reached. The study uses Partial Least Squares Structural Equation Modeling (PLS-SEM) for analytical reasons. This method is carried out using SmartPLS software, which is ideal for handling latent constructs with many indicators and for estimating complex predictive models. The validity and reliability of the results are guaranteed by this scientific approach, which offers both strong measurement assessment and structural model evaluation.

Instrumentation

This survey is based on 28 questions in total. Demographic based questions are based on gender, age, qualification, profession, income level and geographical location. We have adapted these questions from (Sun & Wang, 2020). For GPB four questions were adapted using (Rusyani, Lavuri, & Gunardi, 2021), four questions are adapted for GPI from (Sun & Wang, 2020), four questions are adapted for GBK from (Keller, 1993), four questions were adapted for EF from (Hartmann & Apaolaza-Ibáñez 2012), four questions were adapted for GA from (Hua & Wang, 2019), four (4) questions are adapted for SN from (Hua & Wang, 2019) and four questions are adapted for PBC from (Alam et al. 2014).

Research Design

Current study employed a primary quantitative research approach with a deductive design to examine the factors influencing green buying intention and green purchase behavior toward solar technology uptake. Since a full sampling frame was unavailable, data from home decision-makers, business owners, commercial managers, industrial executives, and potential solar adopters across Pakistan was gathered using purposeful sampling. A sample size of 385 respondents with a 5% margin of error and a 95% confidence level was determined using Cochran's formula; nevertheless, 380 correct answers were gathered.

Measurement Items

For current study four (4) items were adapted from (Lavuri, 2022; Vironika & Maulida, 2025) for GPB. Twelve (12) items were adapted from (Asif et al., 2023; Vironika & Maulida, 2025) for EF. Four (4)

items were adapted from (Asif et al., 2023; Sun & Wang, 2020) for GA. Four (4) items were adapted from (Asif et al., 2023) for SN. Four (4) items were adapted from (Asif et al., 2023) for PBC. Four (4) items were adapted from (Hasheem, Wang, Ye, Farooq, & Shahid, 2022) for GPI. Five (5) items were adapted from (Siyal et al., 2021) for GBK.

RESULTS

Demographic Analysis

Table 1: Demographic profile (n =380)

	Demographic	Frequency	%
Gender	Male	224	59%
	Female	156	41%
Age	≤ 30	149	39%
	31 – 50	175	46%
	> 50	56	15%
Qualification	Under Graduate	115	30%
	Graduate	137	36%
	Post Graduate	128	34%
Marital Status	Married	227	60%
	Single	153	40%
Residence	Urban	159	42%
	Semi Urban	133	35%
	Rural	88	23%

Table 2 describes that a total of 380 people participated in the survey, 59% of respondents were men, 46% were between the ages of 31 and 50, and 36% were graduates, 60% of them were married and 42% belonged to urban area.

Convergent Validity

Average Variance Extracted (AVE), Composite Reliability (CR), and factor loadings are used to evaluate convergent validity.

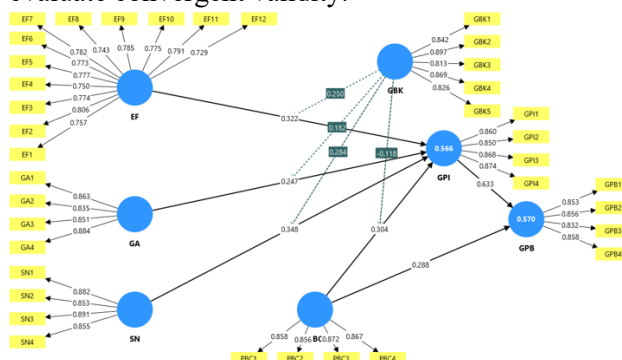


Figure 2: Convergent validity

According to figure 3 adequate internal consistency was confirmed by the fact that all constructs had AVE values over 0.50, factor loadings were high enough, and CR values were higher than the suggested criterion of 0.70. These findings show that the assessment items successfully converge to measure their intended constructs, suggesting a viable and trustworthy measurement model appropriate for more investigation.

Table 3: Convergent validity

Constructs	Items	Loadings	AVE	CA	CR
Green Purchase Behavior	GPB1	0.853	0.872	0.872	0.722
	GPB2	0.856			
	GPB3	0.832			
	GPB4	0.858			
	EF1	0.757			
Environmental Factors	EF2	0.806	0.938	0.939	0.594
	EF3	0.774			
	EF4	0.750			
	EF5	0.777			
	EF6	0.773			
	EF7	0.782			
	EF8	0.743			
	EF9	0.785			
	EF10	0.778			
	EF11	0.788			
Green Attitude	GA1	0.863	0.882	0.891	0.737
	GA2	0.835			
	GA3	0.851			
	GA4	0.884			
Subjective Norms	SN1	0.882	0.893	0.900	0.757
	SN2	0.853			
	SN3	0.891			
	SN4	0.855			
Perceived Behavioral Control	PBC1	0.858	0.886	0.889	0.745
	PBC2	0.856			
	PBC3	0.872			
	PBC4	0.867			
Green Brand Knowledge	GBK1	0.842	0.905	0.944	0.722
	GBK2	0.897			
	GBK3	0.813			
	GBK4	0.869			
	GBK5	0.826			
Green Purchase Intention	GPI1	0.860	0.886	0.886	0.745
	GPI2	0.850			
	GPI3	0.868			
	GPI4	0.874			

Table 4 confirms satisfactory convergent validity, with all factor loadings exceeding 0.70, Cronbach's Alpha and Composite Reliability values above 0.70, and AVE values greater than 0.50. These results demonstrate shetrong reliability, internal consistency, and adequate convergent validity, indicating that the measurement model is suitable for structural model analysis.

Correlation Analysis

A statistical method for determining the direction and degree of a relationship between two or more variables is correlation analysis.

Table 5: Correlation analysis

	R-square	R-square adjusted
GPB	0.570	0.567
GPI	0.566	0.555

According to table 6, the current model explains 57% of the variance in GPB and a substantial 56.6% of the variance in GPI, with adjusted R² values (56.7% and 55.5% respectively) confirming the model's stability and strong explanatory power.

Discriminant Validity

The degree to which a concept in a model is actually different from other constructs is known as discriminant validity. It guarantees that a variable is not unduly correlated with another variable and measures what it is supposed to measure.

HTMT Analysis

Table 7: HTMT Analysis

	EF	GA	GBK	GPB	GPI	PBC	SN
EF							
GA	0.127						
GBK	0.045	0.049					
GPB	0.240	0.146	0.058				
GPI	0.356	0.238	0.047	0.797			
PBC	0.040	0.114	0.071	0.497	0.265		
SN	0.053	0.040	0.085	0.304	0.389	0.114	

According to table 8, all HTMT values fall between 0.040 and 0.797, which is below the suggested cutoff point of 0.90 and indicates adequate discriminant validity. Between Green Purchase Intention (GPI) and Green Purchase Behavior (GPB), the highest HTMT score (0.797) is still within the permissible range. As a result, every construct is empirically unique, demonstrating the measurement model's suitability.

PLS SEM Analysis

Predictive modeling and exploratory research frequently employ smart PLS (Partial Least Squares-Structural Equation Modeling, or PLS-SEM). A statistical method for examining the relationship between one or more independent variables and one or more dependent variables is regression analysis. In this work, the mediation role of GPI has been used to examine the indirect association between IVs (EF, GA, SN, and PBC) and the DV (GPB). Concurrently, the moderating function of GBK in the link between IVs (EF, GA, SN, and PBC) and the mediator GPI has been evaluated.

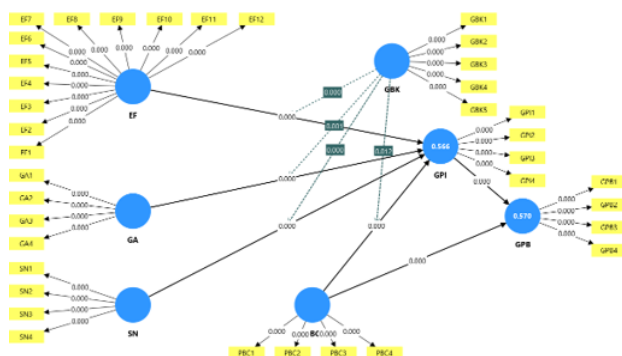


Figure 4: Bootstrapping image

According to figure 5 the PLS-SEM model, GPI and PBC strongly predict GPB, while EF, GA, SN, and PBC significantly affect GPI. While the model explains 56.6% of GPI and 57.0% of GPB variation, GBK moderates a number of associations with GPI.

Direct Analysis

To ascertain each independent variable's unique contribution, direct analysis looks at the independent factors' unmediated and unmoderated impacts on the dependent variable. This study examines the direct impacts of Environmental Factors (EF), Green Attitude (GA), Subjective Norms (SN), and Perceived Behavioral Control (PBC) on Green Purchase Intention (GPI), as well as the direct effects of PBC and GPI on Green Purchase Behavior (GPB).

Table 9: Direct analysis

Hypotheses	Relation	Beta (n)	T Values	P values	Results
H ₁	EF → GPI	0.322	8.675	0.000	Supported
H ₂	GA → GPI	0.247	6.560	0.000	Supported
H ₃	SN → GPI	0.348	9.541	0.000	Supported
H ₄	PBC → GPI	0.304	7.933	0.000	Supported
H ₅	PBC → GPB	0.288	8.854	0.000	Supported
H ₆	GPI → GPB	0.633	20.994	0.000	Supported

Table 10 explains that hypotheses H₁–H₆ are supported, which shows that all proposed direct correlations are positive and statistically significant ($p < 0.001$). Green Purchase Intention ($\beta = 0.633$) has the greatest positive impact on Green Purchase Behavior among the variables, underscoring its crucial function in influencing green purchasing choices.

Mediation Analysis

Green Purchase Intention (GPI) was investigated in the mediation analysis as the mediating variable in the associations between Green Purchase Behavior (GPB) and Environmental Factors (EF), Green Attitude (GA), Subjective Norms (SN), and Perceived Behavioral Control (PBC). In order to elucidate the mechanism behind green purchasing behavior, this analysis ascertains if these variables have an indirect impact on GPB through GPI.

Table 11: Mediation analysis

Hypotheses	Relations	Beta (n)	T Values	P Values	Results
H _{1a}	EF → GPI → GPB	0.204	8.099	0.000	Supported
H _{2a}	GA → GPI → GPB	0.156	6.315	0.000	Supported
H _{3a}	SN → GPI → GPB	0.229	8.366	0.000	Supported
H _{4a}	PBC → GPI → GPB	0.192	8.414	0.000	Supported

According to table 12, hypotheses H_{1a}–H_{4a} are supported, which demonstrates that Green Purchase Intention (GPI) significantly influences the interactions between Environmental Factors, Green Attitude, Subjective Norms, Perceived Behavioral Control, and Green Purchase Behavior ($p < 0.001$). Subjective norms ($\beta = 0.229$) show the largest mediated influence on green purchase behavior among the indirect effects.

Moderation Analysis

The moderating influence of Green Brand Knowledge (GBK) on the associations between Environmental Factors (EF) and Green Purchase

Intention (GPI), Green Attitude (GA) and GPI, Subjective Norms (SN) and GPI, and Perceived Behavioral Control (PBC) and GPI were investigated in the moderation analysis.

Table 13: Moderation analysis

Hypotheses	Relations	Beta (n)	T Values	P values	Results
H1b	GBK x EF → GPI	0.250	4.028	0.000	Supported
H2b	GBK x GA → GPI	0.182	3.352	0.001	Supported
H3b	GBK x SN → GPI	0.284	4.238	0.000	Supported
H4b	GBK x PBC → GPI	-0.118	2.523	0.012	Supported

Table 14 demonstrates that all interaction effects are statistically significant ($p < 0.05$), and Green Brand Knowledge (GBK) significantly moderates the relationships between Environmental Factors, Green Attitude, Subjective Norms, Perceived Behavioral Control, and Green Purchase Intention. $GBK \times$ Subjective Norms has the strongest moderating effect ($\beta = 0.283$), but $GBK \times$ PBC has a significant negative moderating effect ($\beta = -0.118$).

DISCUSSION

By demonstrating that Environmental Factors (EF), Green Attitude (GA), Subjective Norms (SN), and Perceived Behavioral Control (PBC) significantly increase Green Purchase Intention (GPI), the results validate the suggested study methodology. The best predictor among these factors was Subjective Norms, underscoring the significance of social influence in promoting environmentally friendly shopping choices. The Theory of Planned conduct, which holds that intention is the direct antecedent of actual conduct, is supported by the fact that Green Purchase Intention likewise had the largest direct effect on Green Purchase Behavior (GPB). Additionally, the mediation study showed that GPI strongly mediates the associations between EF, GA, SN, PBC, and GPB, suggesting that these factors affect customers' intentions to make purchases. Furthermore, all suggested associations with GPI were considerably mitigated by Green Brand Knowledge (GBK). While the interaction between GBK and PBC was negative, EF, GA, and SN showed positive moderation, indicating that informed customers rely less on perceived behavioral control when establishing buy intentions. Overall, the results show that adding Green Brand Knowledge improves the suggested TPB-based model's capacity to describe green consumer behavior.

CONCLUSION

According to the study's findings, EF, GA, SN, and PBC all have an impact on GPI, which in turn has a

considerable impact on GPB. By converting these factors into real purchasing behavior, the results validate that GPI plays a major mediating role. Additionally, the connections between the antecedent variables and GPI are strongly moderated by GBK, underscoring its significance in bolstering customers' sustainable purchase decisions. The expanded Theory of Planned Behavior's usefulness in understanding GPB is supported by the suggested model, which exhibits enough explanatory power. These results imply that through effective communication and educational programs, legislators, marketers, and green product producers should raise environmental awareness, encourage favorable attitudes, use social influence, and increase customers' knowledge of green brands. All things considered, this study adds to the body of knowledge on sustainable consumer behavior by presenting actual data on the major determinants of green purchasing decisions and practical recommendations for encouraging ecologically conscious shopping.

PRACTICAL IMPLICATIONS

According to the findings, companies, marketers, and legislators should raise consumer understanding of solar benefits, return on investment, environmental impact, and potential government incentives in order to increase solar adoption. In addition to lowering financial and installation barriers through flexible financing and streamlined services, they could increase confidence by emphasizing certifications, client endorsements, community adoption, and referral programs. Consumer adoption of solar energy can also be boosted by supporting smart solar technologies, offering dependable post-installation assistance, and pushing for favorable government regulations.

LIMITATIONS

The results of this study may not apply to other areas or nations with distinct cultural, environmental, and technical settings because it is restricted to Punjab, Pakistan. Results may vary if other theories, factors, or renewable energy sources are considered because the research is based on the Extended Theory of Planned Behavior (TPB) and only focuses on solar technology employing certain variables. Furthermore, the results' depth and generalizability may be hampered by the use of purposeful sampling, a questionnaire-based quantitative design, and

restricted physical data collecting because of budgetary limitations.

FUTURE LINES OF THE STUDY

Future research should examine the consumer decision-making process from purchase intention to post-adoption behavior and compare solar adoption across subsidized and non-subsidized regions, developed and developing countries, and conventional versus smart solar technologies. Further studies should investigate the roles of social influence, word-of-mouth, influencer marketing, AI-powered energy management, and green consumer identity in shaping solar adoption. Researchers should also explore how misinformation, perceived installation complexity, efficiency concerns, and psychological factors influence consumers' willingness to invest in solar technology.

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