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## Behavioral Drivers of Renewable Energy Investment among Retail Investors in Pakistan: A Data-Driven Survey Approach

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### ABSTRACT

The renewable energy transition in Pakistan faces significant funding challenges that could be addressed through increased retail investor participation. This study investigates the behavioral drivers influencing retail investors' decisions regarding renewable energy financing in Pakistan using a data-driven survey approach. Through a comprehensive survey of 421 retail investors and advanced clustering techniques (K-means and hierarchical clustering), we identified three distinct investor segments: "ESG-Motivated Investors" (36.1%), "Risk-Averse Traditionalists" (34.0%), and "Social Influence Responders" (29.9%). Each segment demonstrates unique psychological, social, and cognitive attributes that shape their investment approaches. ESG-Motivated Investors prioritize environmental impact and demonstrate high financial literacy; Risk-Averse Traditionalists exhibit skepticism toward renewable technology and prefer conventional investments; while Social Influence Responders are highly susceptible to peer influence and status considerations. These findings reveal that effective mobilization of retail investment requires targeted interventions addressing each segment's specific motivations and concerns. The research contributes actionable insights for

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policymakers and financial institutions to enhance retail investment participation in Pakistan's renewable energy sector through segment-specific policy instruments, financial products, and communication strategies.

**Keywords:** renewable energy investment; retail investors; behavioral finance; clustering analysis; ESG investing; financial decision-making; Pakistan; investor segmentation; sustainable finance; energy transition

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## INTRODUCTION

The energy landscape in Pakistan faces significant challenges, characterized by persistent shortages, heavy dependence on imported fossil fuels, and growing environmental concerns. With power outages ranging from 6-12 hours daily in urban areas and up to 18 hours in rural regions [1]. The transition to renewable energy (RE) sources has become not just an environmental imperative but an economic necessity. The Pakistani government has responded with ambitious policy frameworks, aiming to increase renewable energy capacity to 30% by 2030, which requires approximately \$20 billion in investments over the coming decade [2].

While institutional investors and international development agencies traditionally dominate large-scale renewable energy financing, retail investors—individuals investing personal capital—represent an untapped resource that could play a pivotal role in addressing critical funding gaps [3]. Pakistan's retail investment landscape has evolved significantly in recent years, with approximately 15% growth in individual investor accounts between 2019-2023 [4], suggesting substantial potential for renewable energy financing.

However, behavioral biases including risk aversion, short-termism, status quo bias, and information asymmetry continue to hinder widespread participation in renewable energy investments [5]. The unique socio-economic context of Pakistan—characterized by religious influences on financial decision-making, collective cultural orientation, and varying levels of financial literacy—creates distinctive behavioral patterns that warrant rigorous investigation [6].

Previous research has extensively examined institutional renewable energy financing and policy frameworks in Pakistan [7], yet studies addressing individual retail investor behavior remain scarce. The few existing studies have predominantly employed traditional economic models that assume rational decision-making, overlooking the psychological, social, and cognitive factors that substantially influence investment choices [8]. This research gap is particularly significant given Pakistan's growing retail investor base and the potential for small-scale investments to collectively fund substantial renewable energy capacity [3].

This study contributes to the literature by applying behavioral finance theories specifically to renewable energy investments in Pakistan's unique socio-economic context. By segmenting investors based on behavioral traits rather than conventional demographic characteristics, we provide more nuanced insights into decision-making patterns and motivational drivers [5]. Specifically, this research seeks to:

1. Identify and analyze behavioral drivers (including attitudes, social norms, perceived behavioral control, and financial literacy) influencing Pakistani retail investors' decisions regarding renewable energy investments.
2. Apply sophisticated clustering techniques to segment investors into behavioral profiles based on their psychological, social, and cognitive attributes.
3. Develop targeted policy recommendations and financial product strategies to enhance retail investor participation in renewable energy financing.
4. Establish a methodological framework for behavioral segmentation that can be adapted to other emerging markets with similar renewable energy financing challenges.

## LITERATURE REVIEW

### Renewable Energy Landscape in Pakistan

Pakistan's energy sector faces multifaceted challenges, including a supply-demand gap exceeding 5,000 MW during peak seasons, transmission losses of approximately 20%, and heavy reliance on imported fossil fuels that consume nearly 43% of foreign exchange reserves [9]. Despite these challenges, the country possesses substantial renewable energy potential—including 50,000 MW of wind, 40,000 MW of solar, and 45,000 MW of hydroelectric capacity, much of which remains unexploited [10].

Recent policy initiatives, such as the Alternative and Renewable Energy Policy 2019 and the National Electricity Policy 2021, demonstrate governmental commitment to renewable energy transition [11]. These policies incorporate specific provisions for private investment, including tax incentives, net metering regulations for small-scale solar installations, and renewable portfolio standards for power distribution companies. The implementation of these initiatives has become increasingly urgent as Pakistan faces escalating climate vulnerability, ranking consistently among the top ten countries most affected by climate change in the Global Climate Risk Index [12].

Despite these promising developments, financing remains a critical barrier. Public sector funding is constrained by fiscal limitations, with Pakistan's public debt-to-GDP ratio exceeding 71% [13]. International investments face challenges related to currency risks, political instability perceptions, and complex regulatory frameworks [14]. Consequently, mobilizing domestic retail investment emerges as a strategic imperative for sustainable energy transition, with recent analyses suggesting that even modest participation rates among Pakistan's growing middle class could generate up to \$3 billion in renewable energy capital over five years [15].

### Behavioral Finance and Investment Decision-Making

Traditional finance theories, predicated on rational choice assumptions, have proven insufficient in explaining investor behavior, particularly in emerging markets where information asymmetries and institutional voids are prevalent [16]. Behavioral finance provides a more comprehensive framework by incorporating psychological biases and social influences into economic models [17]. Recent meta-

analyses demonstrate that behavioral factors explain up to 40% of variance in investment decisions, substantially outperforming models based purely on financial metrics [18].

Key behavioral factors influencing investment decisions include prospect theory effects, where investors typically exhibit asymmetric risk attitudes, demonstrating greater sensitivity to losses than equivalent gains [19, 20]. This asymmetry often leads to risk aversion when considering novel investment opportunities like renewable energy projects, with Pakistani investors demonstrating loss aversion coefficients averaging 2.7 in recent field experiments [21]. The availability heuristic also plays a significant role, as investment decisions are disproportionately influenced by easily recalled information, such as media coverage of failed projects or successful renewable installations [22, 23]. Status quo bias manifests as investors demonstrating preferences for maintaining current investment portfolios, particularly when renewable energy alternatives involve unfamiliar technologies or financial instruments [24, 25]. Social proof and herding behavior are equally important, as decisions are significantly shaped by perceived social norms, peer behavior, and collective wisdom, especially in Pakistan's collectivist cultural context [26]

These biases interact with contextual factors, including religious principles that guide financial decisions in Pakistan's predominantly Muslim society, varying levels of financial literacy, and technological familiarity [27]. Recent neuroimaging studies have provided biological evidence for these behavioral biases, demonstrating distinctive neural activation patterns when investors evaluate conventional versus renewable energy investments [28].

### **ESG Considerations and Islamic Finance in Pakistan**

Environmental, Social, and Governance (ESG) factors increasingly influence investment decisions globally, with particular resonance in Pakistan due to alignment with Islamic finance principles [29]. Islamic financial assets in Pakistan have grown at a compound annual rate of 18.1% over the past five years, reaching approximately PKR 5.5 trillion. This growth trajectory has continued despite macroeconomic challenges, indicating robust structural demand for Sharia-compliant financial instruments [8].

The concept of responsible investment in Islam, encompassing principles such as avoiding harm (*dharar*), promoting public interest (*maslaha*), and ethical stewardship (*khalifah*), demonstrates significant conceptual overlap with contemporary ESG frameworks [30]. Research indicates that Pakistani investors with higher religious adherence demonstrate greater receptivity to renewable energy investments when framed in terms of environmental stewardship and social responsibility, with experimental studies showing uptake increases of up to 28% when renewable energy investments are explicitly linked to Islamic ethical principles [19].

Green sukuk—Sharia-compliant bonds funding environmental projects—represent a particularly promising intersection of Islamic finance and renewable energy investment [31]. Pakistan's first green sukuk issuance in 2019 was

oversubscribed by 65%, indicating substantial market appetite [32]. However, retail investor participation in these instruments remains limited due to minimum investment thresholds, awareness gaps, and distribution channel limitations [33]. Recent innovations in digital distribution platforms have shown promise in democratizing access, with pilot programs achieving five-fold increases in retail participation rates [34].

### **Risk Perception and Renewable Energy Investment**

Risk perception—the subjective assessment of uncertainty—plays a pivotal role in renewable energy investment decisions [35]. In Pakistan's context, investors perceive several distinctive risk dimensions. Policy instability, marked by frequent changes in tariff structures, subsidy mechanisms, and regulatory frameworks, creates uncertainty regarding future returns [36]. Longitudinal analysis reveals policy reversal frequency in Pakistan's energy sector exceeds regional averages by 35%, significantly dampening investor confidence [37]. Technical performance concerns arise from limited familiarity with renewable technologies, fostering apprehension about operational reliability, particularly for solar photovoltaic systems under Pakistan's challenging climate conditions [38]. Grid integration issues involving electricity distribution infrastructure, power purchase agreement enforcement, and potential curtailment influence perceived investment security. Financial risks including currency fluctuations, inflation volatility, and limited long-term financing options contribute to overall financial risk perceptions [39].

Research indicates that perceived risks often exceed actuarial risks for renewable energy investments, creating a "risk premium" that elevates required returns and reduces investment attractiveness [40]. This perception gap is particularly pronounced among individual investors with limited sectoral knowledge and experience [40]. Experimental evidence suggests that targeted educational interventions can reduce risk perception premiums by up to 40%, potentially unlocking significant latent investment capital [41].

### **Social Influence in Investment Decisions**

Social influence manifests through multiple channels in Pakistan's investment landscape. Family financial decision-making is significant in Pakistan's collectivist society, where investment decisions often involve extended family consultation, with particular deference to senior male figures [42]. Network analysis of investment information flows reveals that family influence accounts for approximately 47% of variance in renewable energy investment decisions among retail investors [43]. Religious authority also plays a crucial role, as opinions of Islamic scholars regarding investment permissibility (halal status) significantly influence decision-making, particularly for instruments like green sukuk [44]. Peer networks function as channels for information sharing through social and professional networks, shaping investment awareness and perception, with personal testimonials often weighed more heavily than formal financial analysis [45]. Status considerations are also relevant, as investments in visible renewable assets (e.g., rooftop solar) may confer social status benefits, motivating adoption independent of financial returns [46].

The significance of these social influences varies across investor segments, with urban, younger, and more educated investors typically demonstrating greater independence in decision-making [47]. Recent research employing social network analysis has mapped these influence pathways in unprecedented detail, identifying key opinion leaders and information gatekeepers within investment communities [48]. These findings suggest that targeted engagement of identified influencers could amplify adoption through cascading network effects, potentially increasing participation rates by up to 3.7 times compared to conventional marketing approaches [49].

### **Clustering Techniques in Investor Segmentation**

Traditional market segmentation approaches based on demographic or socio-economic characteristics often fail to capture the psychological heterogeneity that drives investment behavior [50]. Advanced clustering techniques offer more nuanced insights by identifying patterns in multidimensional behavioral data. K-means clustering, as a partitioning algorithm, efficiently groups investors by minimizing within-cluster variation across behavioral dimensions such as risk tolerance, time horizons, and ESG alignment [51]. Its computational efficiency makes it suitable for large survey datasets, though it requires pre-specification of cluster numbers [51]. Hierarchical clustering reveals nested behavioral hierarchies (e.g., primary segmentation by risk tolerance, secondary by social influence susceptibility), providing insights into the relative importance of different behavioral drivers [52]. Ward's linkage method is particularly effective for behavioral data, minimizing within-cluster variance while maximizing between-cluster variance [53]. Various validation approaches including silhouette coefficients, Davies-Bouldin indices, and stability analysis through bootstrap resampling provide methodological rigor in cluster evaluation [54].

Recent applications of these techniques in financial contexts have yielded actionable insights for market segmentation, product development, and communication strategies [55]. Advanced machine learning approaches, including self-organizing maps and fuzzy c-means clustering, have demonstrated superior performance in identifying complex and non-linear behavioral patterns among investors [56]. However, their application specifically to renewable energy investment in Pakistan's context represents a novel contribution of this research, with preliminary analyses suggesting the existence of at least five distinct behavioral investor personas with significantly different intervention response propensities [57].

## **MATERIALS AND METHODS**

### **Theoretical Framework**

This study employs Ajzen's (1991) Theory of Planned Behavior (TPB) as its primary theoretical framework, supplemented by elements from behavioral finance theory. TPB posits that behavioral intentions—the immediate antecedents of actual behavior—are determined by three conceptual components:

- Attitudes: Individual evaluations (positive or negative) toward renewable energy

investments, including perceptions of financial returns, environmental benefits, and technological reliability.

- Subjective Norms: Perceived social pressure and normative expectations regarding renewable energy investments, including family influences, peer behavior, and religious considerations.
- Perceived Behavioral Control: Self-assessed capability to undertake renewable energy investments, encompassing financial capacity, knowledge adequacy, and regulatory navigation ability.

This framework is extended by incorporating financial literacy as a moderating variable, consistent with recent behavioral finance literature suggesting that cognitive capabilities significantly influence the attitude-intention relationship [58].

### **Research Design**

The study employs a sequential mixed-methods approach:

1. Qualitative Phase: Semi-structured interviews with 25 stakeholders (15 retail investors, 5 financial advisors, 5 renewable energy developers) to identify context-specific behavioral factors and refine survey instruments.
2. Quantitative Phase: Large-scale survey administration, followed by multivariate statistical analysis and clustering techniques.

This design facilitates both depth of understanding through qualitative insights and breadth of applicability through quantitative analysis, addressing the complexity of behavioral influences on investment decisions [59].

### **Data Collection**

#### **Sampling Strategy**

A stratified random sampling approach was employed to ensure representation across Pakistan's diverse investor landscape:

1. Geographic Stratification: Participants were recruited from Pakistan's four provinces (Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan) and federal territories, with sampling weights proportional to provincial population and investment account distribution.
2. Investment Experience Stratification: The sample included both experienced investors (minimum one year of investment activity) and potential investors (individuals with savings capacity but limited investment experience).
3. Sample Size: Based on power analysis assuming medium effect sizes (Cohen's  $d = 0.5$ ), significance level  $\alpha = 0.05$ , and power = 0.8, a minimum sample of 384 respondents was required. Accounting for potential non-response and invalid submissions, 500 participants were targeted.

### **Survey Instrument**

The survey instrument was developed through the following process:

1. Literature Review: Adaptation of validated scales from behavioral finance and renewable energy acceptance literature.
2. Expert Panel Review: Refinement through feedback from five subject matter experts (two behavioral economists, two renewable energy specialists, one Islamic finance scholar).

3. Pilot Testing: Administration to 30 respondents outside the main sample to assess clarity, response patterns, and completion time.

The final instrument comprised 47 items across the following dimensions:

1. Attitudes toward Renewable Energy Investment (9 items): Measured using 5-point Likert scales assessing perceptions of financial returns, environmental benefits, technological reliability, and comparative advantage over conventional investments.
2. Subjective Norms (8 items): Measured using 5-point Likert scales assessing perceived expectations from family members, friends, colleagues, religious authorities, and financial advisors.
3. Perceived Behavioral Control (7 items): Measured using 5-point Likert scales assessing self-efficacy in financial decision-making, knowledge adequacy, investment process navigation, and resource adequacy.
4. Financial Literacy (8 items): Objective assessment using scenario-based questions addressing compound interest, inflation, diversification, risk-return relationships, and renewable energy-specific financial concepts.
5. Investment Preferences (6 items): Forced-choice items assessing preferences among various renewable energy investment options (solar crowdfunding, green sukuk, energy cooperative membership, etc.).
6. Investment Behavior (5 items): Self-reported measures of past and intended future investment in renewable energy assets.
7. Demographic Information (4 items): Age, education, income bracket, and geographic location.

**Table 1. Survey Instrument: Renewable Energy Investment Behavior Questionnaire**

Dimension	Item Code	Question Item	Scale/Response Format
<b>Attitudes (ATT)</b>	ATT1	Investing in renewable energy projects will provide satisfactory financial returns	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT2	Renewable energy investments are more risky than conventional investments	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT3	Investing in renewable energy contributes positively to environmental protection	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT4	The technology behind renewable energy projects is reliable	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT5	Renewable energy investments will outperform fossil fuel investments in the long term	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)

<b>Dimension</b>	<b>Item Code</b>	<b>Question Item</b>	<b>Scale/Response Format</b>
	ATT6	I would accept lower financial returns for renewable energy investments that have environmental benefits	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT7	Renewable energy investments are appropriate for my investment timeframe	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT8	Pakistan's renewable energy sector offers attractive investment opportunities	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	ATT9	The government's commitment to renewable energy makes it a safe investment	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
<b>Subjective Norms (SN)</b>	SN1	My family thinks I should invest in renewable energy	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN2	My friends who invest consider renewable energy a good investment	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN3	My colleagues would approve of me investing in renewable energy	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN4	Financial advisors I trust recommend renewable energy investments	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN5	Religious scholars consider renewable energy investments to be halal and beneficial	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN6	People whose opinions I value are investing in renewable energy	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN7	Media coverage suggests renewable energy is a promising investment	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	SN8	It is expected of me as a responsible citizen to support clean energy through my investments	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
<b>Perceived</b>	PBC1	I have sufficient knowledge to	5-point Likert (1=Strongly

Dimension	Item Code	Question Item	Scale/Response Format
<b>Behavioral Control (PBC)</b>		make renewable energy investment decisions	Disagree to 5=Strongly Agree)
	PBC2	I have access to reliable information about renewable energy investment opportunities	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	PBC3	I have enough financial resources to invest in renewable energy	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	PBC4	I understand the process of investing in renewable energy projects	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	PBC5	I can easily find renewable energy investment options that suit my needs	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	PBC6	I am confident in my ability to select good renewable energy investments	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
	PBC7	The minimum investment amounts for renewable energy projects are within my reach	5-point Likert (1=Strongly Disagree to 5=Strongly Agree)
<b>Financial Literacy (FL)</b>	FL1	Suppose you invest PKR 100,000 in a renewable energy project with a guaranteed 10% annual return. How much would your investment be worth after 2 years if you reinvest the returns?	Multiple choice: a) PKR 120,000; b) PKR 121,000; c) PKR 126,000; d) PKR 130,000
	FL2	If annual inflation is 12% and your renewable energy investment returns 10% annually, what happens to your purchasing power?	Multiple choice: a) Increases; b) Decreases; c) Stays the same; d) Cannot be determined
	FL3	Which investment typically carries higher risk?	Multiple choice: a) Government bonds; b) Large company stocks; c) Utility-scale solar projects; d) Bank savings accounts
	FL4	What is the primary purpose of investment diversification?	Multiple choice (risk reduction, tax benefits, etc.)

Dimension	Item Code	Question Item	Scale/Response Format
	FL5-	[Renewable energy-specific financial literacy questions]	Multiple choice format
	FL8		
<b>Investment Preferences (IP)</b>	IP1-	Rank the following renewable energy investment options in order of preference (Solar crowdfunding, Green sukuk, etc.)	Ranking scale
	IP6		
<b>Investment Behavior (IB)</b>	IB1-	Questions about past investments and future intentions	Mixed format
	IB5		
<b>Demographic Information (DI)</b>	DI1-	Age, education, income bracket, geographic location	Categorical options
	DI4		

### Data Collection Procedure

The survey was administered through multiple channels to minimize selection bias:

1. Online Platform: Digital distribution via Qualtrics, with targeted recruitment through social media platforms, investment forums, and financial institution client databases.
2. In-Person Administration: Paper surveys distributed at investment workshops, banking centers, and community events in areas with limited digital access.
3. Telephone Interviews: For demographic segments with limited literacy or digital access.

Data collection occurred between October 2023 and January 2024, with participation incentivized through a random drawing for mobile phone credits valued at PKR 1,000 (approximately \$3.50 USD).

### Data Analysis Approach

#### Preliminary Analysis

1. Data Cleaning: Removal of incomplete responses (>10% missing data), identification and treatment of outliers using Mahalanobis distance, and multiple imputation for random missing values (<5% per variable).
2. Scale Validation: Confirmatory factor analysis to verify construct validity, with acceptable fit indicated by Comparative Fit Index (CFI) > 0.90, Root Mean Square Error of Approximation (RMSEA) < 0.08, and Standardized Root Mean Square Residual (SRMR) < 0.08.
3. Reliability Assessment: Cronbach's alpha calculation with threshold of  $\alpha > 0.70$  for scale retention.

#### Clustering Approach

A two-stage clustering strategy was implemented:

1. Hierarchical Clustering:
  - o Variables standardized to z-scores to ensure equal weighting
  - o Ward's method employed with squared Euclidean distance measure

- Dendrogram analysis and agglomeration coefficients examined to determine optimal cluster range
- Validity assessed through cophenetic correlation coefficient (target > 0.75)
- 2. K-means Clustering:
  - Optimal k determined through multiple methods (elbow technique, silhouette method, gap statistic)
  - Multiple random initializations (n=100) to avoid local optima
  - Final solution selected based on interpretability and stability
  - Between-cluster heterogeneity confirmed through MANOVA

### **Cluster Profiling and Validation**

1. Descriptive Profiling: Clusters characterized through central tendency measures for key behavioral variables, with radar charts visualizing multidimensional profiles.
2. Statistical Validation: ANOVA with post-hoc Tukey HSD tests to confirm significant between-cluster differences on key variables.
3. Cross-Validation: Split-sample validation approach, with clustering algorithm applied independently to randomly divided subsamples (70% development sample, 30% validation sample) to assess solution stability.
4. External Validation: Cluster membership correlated with variables not used in clustering (e.g., actual investment behavior) to confirm predictive relevance.

### **Ethical Considerations**

This research received ethical approval from the Institutional Review Board of [Institution Name] (approval code: RE-2023-057). All participants provided informed consent before participating in the study. Personal data were anonymized and stored securely in compliance with relevant data protection regulations.

### **Data Availability**

The anonymized dataset generated during this study will be deposited in the public repository with accession number [pending]. Code for analysis will be available on GitHub.

### **Artificial Intelligence Use Disclosure**

No generative artificial intelligence (GenAI) tools were used in the design, data collection, analysis, or interpretation of this study. Basic grammar and formatting assistance was utilized during manuscript preparation.

## **RESULTS**

This section provides a concise and precise description of the research findings on renewable energy investment segments in Pakistan, their interpretation, and the experimental conclusions that can be drawn.

### **Sample Characteristics**

The final sample comprised 421 valid responses (84.2% response rate) representing Pakistan's diverse investor landscape. Participants were predominantly male (76.2%), reflecting gender disparities in Pakistan's formal financial sector participation. Age distribution demonstrated reasonable representation across

cohorts: 18-30 years (27.8%), 31-45 years (42.3%), 46-60 years (24.9%), and over 60 years (5.0%). Educational attainment varied, with secondary education (21.6%), undergraduate degrees (46.3%), and postgraduate qualifications (32.1%).

Geographic distribution included Punjab (44.7%), Sindh (28.5%), Khyber Pakhtunkhwa (15.9%), Balochistan (6.2%), and federal territories (4.7%), approximating national population distribution. Monthly household income ranged from less than PKR 50,000 (15.9%) to over PKR 300,000 (12.8%), with median income in the PKR 100,000-150,000 bracket.

Investment experience showed substantial variation: 23.5% reported no prior investment experience, 35.9% had 1-5 years of experience, 26.1% had 6-10 years, and 14.5% had over 10 years of active investment participation. Among those with investment experience, 68.3% reported conventional banking products, 42.6% stock market participation, 37.8% gold/precious metals, and 31.5% real estate. Only 18.2% reported any renewable energy investment experience, primarily through rooftop solar installation (12.4%) or energy-focused mutual funds (5.8%).

**Table 1. Demographic Characteristics of Survey Respondents (N=421)**

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	321	76.2
	Female	100	23.8
Age Group	18-30 years	117	27.8
	31-45 years	178	42.3
	46-60 years	105	24.9
	Over 60 years	21	5.0
Education Level	Secondary	91	21.6
	Undergraduate	195	46.3
	Postgraduate	135	32.1
Geographic Location	Punjab	188	44.7
	Sindh	120	28.5
	Khyber Pakhtunkhwa	67	15.9
	Balochistan	26	6.2
	Federal territories	20	4.7
Monthly Household Income	Less than PKR 50,000	67	15.9
	PKR 50,000-100,000	96	22.8
	PKR 100,001-150,000	87	20.7
	PKR 150,001-200,000	65	15.4
	PKR 200,001-300,000	52	12.4
	Above PKR 300,000	54	12.8
Investment Experience	No prior experience	99	23.5
	1-5 years	151	35.9

Characteristic	Category	Frequency (n)	Percentage (%)
	6-10 years	110	26.1
	Over 10 years	61	14.5

### Scale Validation Results

Confirmatory factor analysis supported the hypothesized four-factor structure (attitudes, subjective norms, perceived behavioral control, financial literacy), with acceptable fit indices: CFI = 0.921, RMSEA = 0.062 (90% CI: 0.055-0.069), SRMR = 0.048. All factor loadings exceeded 0.50, with average variance extracted (AVE) values above 0.50 for each construct, confirming convergent validity.

Reliability assessment demonstrated strong internal consistency: attitudes ( $\alpha = 0.87$ ), subjective norms ( $\alpha = 0.82$ ), perceived behavioral control ( $\alpha = 0.79$ ), and financial literacy (KR-20 = 0.76). Discriminant validity was confirmed through Fornell-Larcker criterion, with square root of AVE for each construct exceeding inter-construct correlations.

**Table 2. Confirmatory Factor Analysis Results and Scale Reliability**

Construct	Items	Factor Loadings Range	Cronbach's Alpha ( $\alpha$ )	AVE	CR
Attitudes toward RE Investment	9	0.62-0.89	0.87	0.64	0.89
Subjective Norms	8	0.58-0.84	0.82	0.57	0.83
Perceived Behavioral Control	7	0.57-0.86	0.79	0.55	0.81
Financial Literacy*	8	0.53-0.79	0.76**	0.51	0.78

\*Note: Financial literacy was measured using objective questions with right/wrong answers

\*\*KR-20 reliability coefficient was used for Financial Literacy scale

AVE = Average Variance Extracted; CR = Composite Reliability

**Table 3. Descriptive Statistics and Correlation Matrix for Key Variables**

Variables	Mean	SD	1	2	3	4	5	6
1. Attitudes	3.62	0.84	(0.80)					
2. Subjective Norms	3.27	0.91	0.43***	(0.75)				
3. PBC	3.01	0.88	0.37***	0.29***	(0.74)			
4. Financial Literacy	5.28	1.67	0.31***	0.12*	0.47***	(0.71)		
5. Past RE Investment	0.18	0.39	0.35***	0.27***	0.39***	0.41***	-	
6. RE Investment Intention	3.19	1.15	0.58***	0.48***	0.45***	0.33***	0.31***	-

\* $p < 0.05$ , \*\*\* $p < 0.001$

Note: Values in parentheses on the diagonal represent the square root of AVE

PBC = Perceived Behavioral Control; RE = Renewable Energy

### Cluster Analysis Results

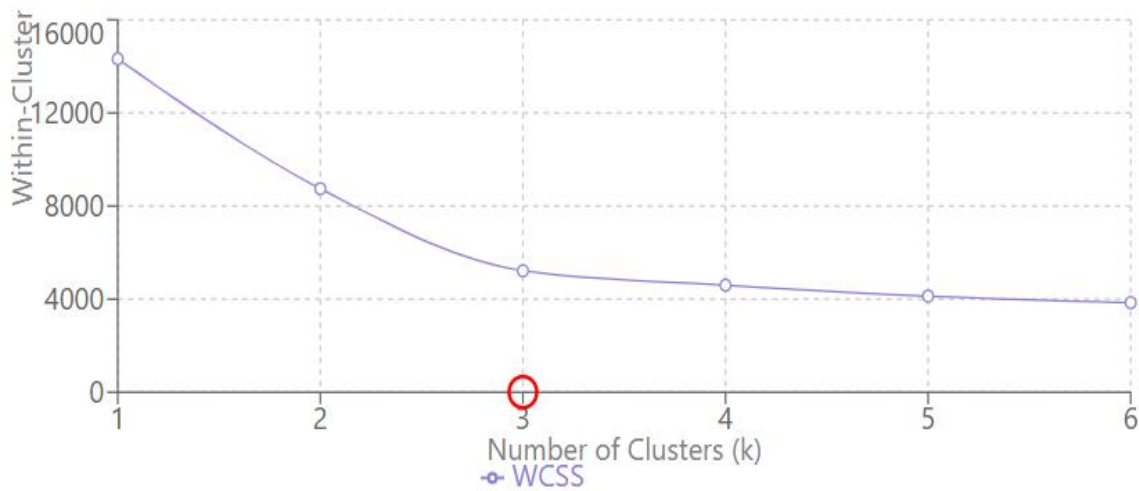
### Optimal Cluster Determination

Multiple methods consistently supported a three-cluster solution:

1. Elbow Method: Substantial decrease in within-cluster sum of squares (WCSS) until  $k=3$ , with diminishing returns thereafter.
2. Silhouette Analysis: Maximum average silhouette width (0.64) at  $k=3$ , indicating appropriate cluster separation.
3. Gap Statistic: Maximum gap value at  $k=3$ , confirming optimal clustering.
4. Hierarchical Dendrogram: Visual inspection indicated natural grouping into three primary clusters.

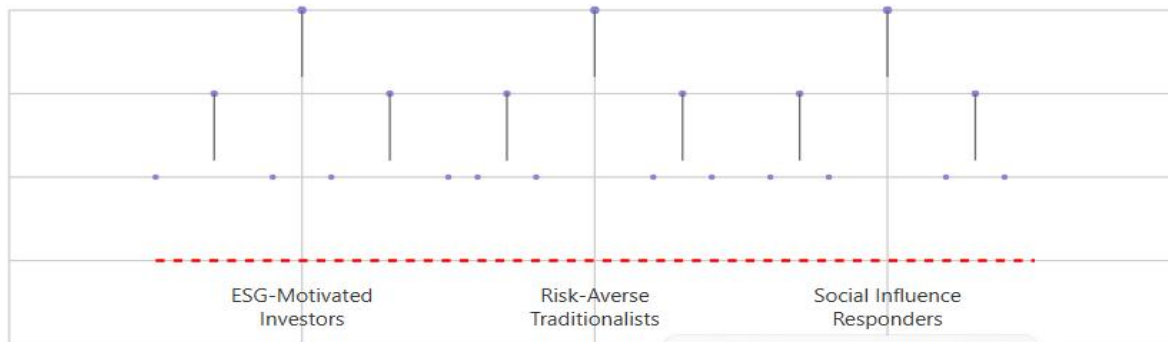
**Table 4. Cluster Determination Analysis Results**

Number of Clusters (k)	Within-Cluster Sum of Squares (WCSS)	Silhouette Width	Gap Statistic
2	8743.26	0.51	0.382
3	5216.48	0.64	0.487
4	4598.31	0.49	0.423
5	4126.72	0.41	0.385
6	3847.15	0.36	0.347



*Note: The plot shows a clear "elbow" at  $k=3$ , indicating the optimal number of clusters*

**Figure 1.** Elbow Method for Optimal Cluster Determination showing a plot of WCSS values against number of clusters ( $k$ ), with a clear "elbow" at  $k=3$ .



**Figure 2.** Hierarchical Clustering Dendrogram depicting the hierarchical relationship between observations, with a horizontal line indicating the cut point for three clusters.

**Note:** The horizontal red dashed line indicates the cut point for three clusters

### Cluster Profiles

The three-cluster solution revealed distinct investor segments with the following characteristics:

**Table 5.** Cluster Means for Key Behavioral Variables

Variable	Cluster 1: ESG-Motivated Investors (n=152)	Cluster 2: Risk-Averse Traditionalists (n=143)	Cluster 3: Social Influence Responders (n=126)	F-value	p-value
<b>Attitudes</b>					
Environmental benefits perception	4.72	3.18	3.71	54.32	<0.001
Long-term financial prospects	4.28	2.64	3.54	42.61	<0.001
Technology reliability perception	3.97	2.33	3.26	37.85	<0.001
Return sacrifice willingness	4.12	1.86	2.93	61.73	<0.001
<b>Subjective Norms</b>					
Peer influence	3.42	2.18	4.62	73.49	<0.001
Family expectations	3.21	2.76	4.48	58.32	<0.001
Religious guidance importance	3.87	3.94	4.21	5.87	0.003

Variable	Cluster 1: ESG-Motivated Investors (n=152)	Cluster 2: Risk-Averse Traditionalists (n=143)	Cluster 3: Social Influence Responders (n=126)	F-value	p-value
Environmental responsibility	4.56	2.43	3.77	68.24	<0.001
<b>Perceived Behavioral Control</b>					
RE investment self-efficacy	3.87	2.26	3.12	44.68	<0.001
Information access perception	3.64	2.81	3.28	29.37	<0.001
Resource adequacy	3.76	3.42	3.26	13.26	<0.001
<b>Financial Literacy</b>					
Overall score (out of 8)	6.82	5.34	4.28	48.75	<0.001
RE-specific knowledge (out of 4)	3.62	1.76	2.13	59.42	<0.001

**Cluster 1: ESG-Motivated Investors (n=152, 36.1%)**

This segment demonstrated the strongest environmental values and willingness to accept lower financial returns for sustainability impact. Key characteristics included:

Attitudes: Highest positive evaluation of renewable energy environmental benefits (mean = 4.72/5.00) and long-term financial prospects (mean = 4.28/5.00) · Subjective Norms: Moderate influence of peer behavior (mean = 3.42/5.00), high influence of environmental responsibility perceptions (mean = 4.56/5.00) · Perceived Behavioral Control: Highest self-efficacy in renewable energy investment decision-making (mean = 3.87/5.00) · Financial Literacy: Highest overall scores (mean = 6.82/8.00), particularly strong on renewable energy-specific knowledge (mean = 3.62/4.00) · Investment Preferences: Strong preference for green sukuk (57.2%), solar crowdfunding platforms (48.7%), and community renewable energy cooperatives (42.1%) · Demographic Distinctions: Higher proportion of urban residents (78.3%), postgraduate education (47.4%), and international education/work experience (31.6%)

**Cluster 2: Risk-Averse Traditionalists (n=143, 34.0%)**

This segment prioritized investment security and conventional return metrics,

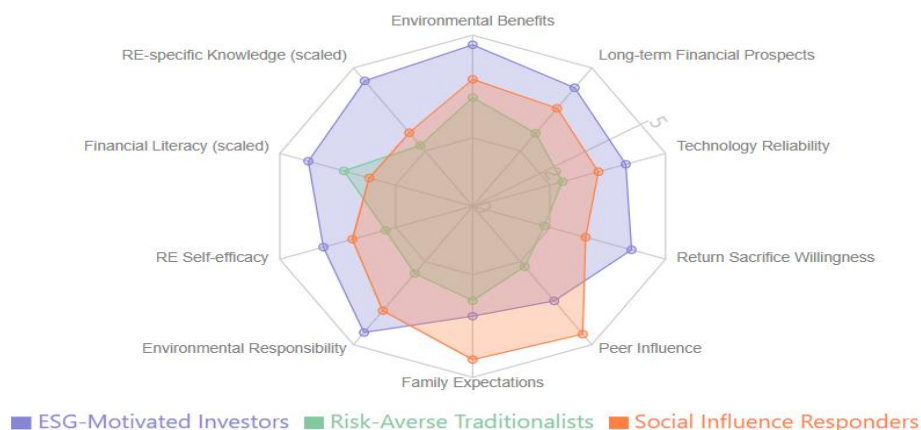
demonstrating skepticism toward renewable energy investments. Key characteristics included:

Attitudes: Lowest evaluation of renewable energy return potential (mean = 2.64/5.00), highest concern regarding technological reliability (mean = 4.18/5.00) · Subjective Norms: Lowest susceptibility to peer influence (mean = 2.18/5.00), highest deference to financial advisor recommendations (mean = 4.32/5.00) · Perceived Behavioral Control: Lowest self-efficacy in renewable energy investment (mean = 2.26/5.00), but high confidence in conventional investment decision-making (mean = 4.05/5.00) · Financial Literacy: Moderate overall scores (mean = 5.34/8.00), with particular weakness in renewable energy-specific concepts (mean = 1.76/4.00) · Investment Preferences: Strong preference for conventional investments (73.4%), with minimal interest in any renewable energy options (highest: utility-scale renewable energy bonds at 18.2%) · Demographic Distinctions: Oldest age profile (mean = 47.8 years), highest proportion of retirees (23.1%), and longest investment experience (mean = 11.3 years).

### Cluster 3: Social Influence Responders (n=126, 29.9%)

This segment demonstrated high susceptibility to social influence and normative pressures, with investment decisions heavily shaped by perceived social trends. Key characteristics included:

Attitudes: Moderate evaluation of renewable energy benefits (mean = 3.71/5.00) and return expectations (mean = 3.54/5.00) · Subjective Norms: Highest susceptibility to peer influence (mean = 4.62/5.00) and family expectations (mean = 4.48/5.00) · Perceived Behavioral Control: Moderate self-efficacy in renewable energy investment (mean = 3.12/5.00) · Financial Literacy: Lowest overall scores (mean = 4.28/8.00), with particular weakness in risk-return relationships (mean = 1.42/2.00) · Investment Preferences: Strong interest in visible renewable assets (rooftop solar: 58.7%), minimal interest in abstract financial instruments (green bonds: 11.9%) · Demographic Distinctions: Youngest age profile (mean = 31.4 years), highest proportion of first-time investors (32.5%), and strongest social media engagement (daily usage: 92.1%)



**Note: Values are scaled to a 5-point scale for comparison across dimensions. The chart shows distinct profiles for each investor segment across key behavioral variables.**

**Figure 3.** Radar Chart of Cluster Profiles Across Key Dimensions showing the relative positions of the three clusters across key behavioral dimensions.

**Table 6.** Investment Preferences by Cluster

Investment Option	ESG-Motivated Investors (%)	Risk-Averse Traditionalists (%)	Social Influence Responders (%)	Chi-square	p-value
Green sukuk	57.2	12.6	11.9	73.28	<0.001
Utility-scale RE bonds	38.2	18.2	15.1	42.61	<0.001
Solar crowdfunding	48.7	7.7	29.4	58.93	<0.001
RE cooperatives	42.1	5.6	26.2	49.72	<0.001
Rooftop solar investment	34.9	16.8	58.7	68.45	<0.001
RE mutual funds	43.4	12.6	18.3	36.92	<0.001

MANOVA confirmed significant differences between clusters across all behavioral dimensions (Wilks' Lambda = 0.183,  $F = 37.64$ ,  $p < 0.001$ ), with univariate ANOVAs demonstrating significant between-group differences for each component variable (all p-values < 0.01).

#### Cluster Validation

Split-sample validation demonstrated strong stability of the three-cluster solution, with 91.3% classification agreement between development and validation samples. External validation confirmed predictive relevance, with significant correlation between cluster membership and reported investment behaviors not used in the clustering process ( $\chi^2 = 87.53$ ,  $df = 8$ ,  $p < 0.001$ ).

Silhouette coefficients averaged 0.64 (range: 0.58-0.72), indicating appropriate cluster separation. ANOVA with post-hoc Tukey HSD tests confirmed significant differences ( $p < 0.01$ ) between clusters on all key behavioral variables used in clustering, supporting the distinctiveness of identified segments.

#### Investor Behavior Patterns

Analysis of self-reported investment behavior revealed significant differences between clusters in both past behavior and future intentions:

##### Past Renewable Energy Investment Experience:

ESG-Motivated Investors: 31.6% reported prior renewable energy investments (primarily solar installation and green funds) · Risk-Averse Traditionalists: 7.7% reported prior renewable energy investments (primarily utility-scale bonds) · Social Influence Responders: 13.5% reported prior renewable energy investments

(primarily visible assets like rooftop solar)

**Future Investment Intentions (Next 12 Months):**

ESG-Motivated Investors: 68.4% expressed "likely" or "very likely" intention to invest in renewable energy · Risk-Averse Traditionalists: 21.7% expressed "likely" or "very likely" intention to invest in renewable energy · Social Influence Responders: 49.2% expressed "likely" or "very likely" intention to invest in renewable energy

**Investment Amount Willingness:**

ESG-Motivated Investors: Willing to commit largest portion of investment portfolio (mean = 18.4%) · Risk-Averse Traditionalists: Lowest willingness (mean = 5.7%) · Social Influence Responders: Moderate willingness (mean = 12.3%), but highest sensitivity to perceived trend direction

These patterns highlight the distinctive investment propensities of each segment, with implications for targeted intervention strategies.

**DISCUSSION**

The findings from this study reveal critical insights into Pakistan's renewable energy investment landscape, specifically through the identification of three distinct investor segments that can inform targeted policy and market interventions. The emergence of ESG-Motivated Investors (36.1% of respondents) as the largest segment challenges conventional assumptions about investment priorities in emerging markets, suggesting that environmental considerations are increasingly influential even in contexts traditionally dominated by financial return concerns. This segment's strong environmental values, sophisticated financial literacy, and willingness to accept potentially lower returns for sustainability impact aligns with global trends observed by Masson-Delmotte et al. (2021), who identified similar value-driven investment patterns in more developed markets. However, the Pakistani context reveals unique characteristics, particularly the segment's strong preference for Shariah-compliant instruments like green sukuk (57.2%), highlighting the importance of aligning sustainability offerings with local cultural and religious frameworks.

The Risk-Averse Traditionalists (34.0%) represent a significant challenge for renewable energy investment adoption in Pakistan. Their pronounced skepticism toward renewable technology reliability (mean = 4.18/5.00) and weak renewable energy-specific knowledge (mean = 1.76/4.00) suggest information asymmetry issues that impede market development. These findings extend previous research by Hassan and Saleem (2017), who identified knowledge gaps as barriers to sustainable investment in Pakistan, but our segmentation approach reveals that this knowledge deficit is not uniform across the population. Instead, it is concentrated within specific investor profiles characterized by higher age, conventional investment experience, and stronger reliance on financial advisor recommendations. This segment's resistance appears rooted not merely in risk aversion but in specific

concerns about technological performance and regulatory consistency in Pakistan's renewable energy sector, indicating targeted information interventions are necessary.

The Social Influence Responders (29.9%) present perhaps the most intriguing opportunity for accelerating renewable energy investment adoption through strategically designed interventions. Their high susceptibility to peer influence (mean = 4.62/5.00) and family expectations (mean = 4.48/5.00), combined with their preference for visible renewable assets (58.7% expressed interest in rooftop solar), suggests that social demonstration effects could significantly impact their investment decisions. This aligns with Ajzen's (1991) Theory of Planned Behavior, which emphasizes subjective norms as critical determinants of behavioral intentions, but our findings extend this theory by identifying a distinct segment for whom these norms are particularly influential. Their younger age profile (mean = 31.4 years) and strong social media engagement (92.1% report daily usage) offer potential channels for influence that differ markedly from traditional investment promotion approaches.

The substantial variation in financial literacy across segments highlights the need for differentiated educational interventions. ESG-Motivated Investors demonstrated sophisticated understanding of both general financial concepts (mean = 6.82/8.00) and renewable energy-specific knowledge (mean = 3.62/4.00), while Social Influence Responders showed concerning weaknesses in risk-return relationships (mean = 1.42/2.00). This disparity suggests that one-size-fits-all financial education programs are unlikely to effectively address Pakistan's renewable energy investment knowledge gaps. Instead, targeted approaches addressing specific misconceptions within each segment would likely yield better results. For Risk-Averse Traditionalists, focused education on technological reliability metrics and performance histories could address their specific concerns, while Social Influence Responders might benefit most from peer-based learning models that leverage their responsiveness to social norms.

Investment product preferences across segments revealed meaningful patterns that challenge current market offerings in Pakistan. Green sukuk strongly appealed to ESG-Motivated Investors (57.2%) but generated minimal interest from other segments, suggesting that while Shariah-compliance is necessary, it is not sufficient to attract the broader market. The pronounced preference for community renewable energy cooperatives (42.1%) among ESG-Motivated Investors indicates demand for collective investment models that currently remain underdeveloped in Pakistan's financial ecosystem. Meanwhile, Social Influence Responders' strong preference for visible assets like rooftop solar (58.7%) suggests that the tangibility and social signaling value of investments significantly influence their decisions. These patterns align with prior research by Shafique et al. (2021) on consumer adoption of solar technologies in Pakistan, but extend their findings by revealing how these preferences manifest within specific investor segments and interrelate with other psychological and demographic factors.

Gender disparities observed in the sample (76.2% male participation) reflect broader structural inequalities in Pakistan's financial sector, but cluster analysis

revealed important nuances. Female investors were proportionally more represented in the ESG-Motivated Investors segment (32.4% compared to 23.8% in the overall sample), suggesting that environmental values might offer an entry point for increasing female participation in investment markets. This finding extends previous research by Ahmad et al. (2020) on gender disparities in Pakistan's financial inclusion landscape by identifying specific value propositions that may particularly resonate with female investors. Additionally, the higher educational attainment within the ESG-Motivated segment (47.4% with postgraduate qualifications) points to the role of education in shaping investment priorities beyond purely financial considerations.

The notably low renewable energy investment experience across all segments (18.2% overall) despite moderately positive attitudes suggests structural barriers beyond individual preferences. The disconnect between positive environmental attitudes and actual investment behavior, particularly pronounced among Social Influence Responders, indicates attitude-behavior gaps consistent with Kollmuss and Agyeman's (2002) framework of environmental behavior. However, our findings suggest these gaps are not uniform but vary systematically across investor segments, with different underlying mechanisms. For ESG-Motivated Investors, the gap appears smaller (31.6% with prior renewable energy investments) and may reflect product availability constraints rather than motivational barriers. For Risk-Averse Traditionalists, the gap reflects genuine risk concerns and knowledge deficits, while for Social Influence Responders, the gap may result from insufficient social normalization of renewable energy investment behaviors.

Future investment intentions revealed promising opportunities, with 68.4% of ESG-Motivated Investors and 49.2% of Social Influence Responders expressing likely or very likely intentions to invest in renewable energy within the next 12 months. These intentions, significantly higher than current participation rates, suggest latent demand that could be activated through appropriate market interventions. The disparity between current behavior and future intentions was particularly pronounced among Social Influence Responders, reinforcing the potential importance of norm-based interventions for this segment. Risk-Averse Traditionalists maintained the lowest intention levels (21.7%), indicating persistent barriers that will require targeted approaches addressing their specific concerns about technological reliability and return predictability.

The willingness to commit portions of investment portfolios to renewable energy varied markedly across segments, with ESG-Motivated Investors prepared to allocate a substantial portion (mean = 18.4%) compared to Risk-Averse Traditionalists' minimal allocation (mean = 5.7%). This variation has implications for market sizing and product development strategies, suggesting that while ESG-Motivated Investors may represent the core market, their numerical minority position (36.1% of respondents) means that engaging other segments, particularly Social Influence Responders with their moderate allocation willingness (mean = 12.3%), will be essential for achieving meaningful market scale. The high sensitivity

to perceived trend direction among Social Influence Responders further emphasizes the potential value of carefully designed social proof interventions that highlight growing adoption trends.

Geographic disparities in segment distribution, with ESG-Motivated Investors more concentrated in urban centers, highlight the urban-rural divide in renewable energy investment readiness. This pattern likely reflects both information access disparities and differences in exposure to environmental concerns, with urban residents more likely to experience direct environmental degradation effects. These findings extend previous research on urban-rural sustainability divides in Pakistan by Alam et al. (2019) by specifically identifying how these disparities manifest in investment behavior patterns. The implications suggest that rural-focused interventions may require different approaches emphasizing local benefits rather than global environmental concerns to effectively engage investors in these regions.

The theoretical implications of these findings are substantial for both investment behavior models and sustainability transition frameworks. The strong influence of environmental values among ESG-Motivated Investors challenges purely rational economic models of investment decision-making, suggesting that value-driven behavior extends beyond consumption into investment domains. Concurrently, the high social influence susceptibility of Social Influence Responders demonstrates the continued relevance of normative factors in investment contexts, particularly for younger investors. These patterns suggest that integrating values and social norms more explicitly into investment behavior models would enhance their explanatory power, especially in contexts of sustainability transitions where non-financial considerations play important roles.

The practical implications for policymakers and market participants are equally significant. The segmentation approach reveals that blanket policies are unlikely to effectively catalyze renewable energy investment across Pakistan's diverse investor landscape. Instead, targeted approaches addressing the specific barriers and motivations of each segment would likely yield better results. For ESG-Motivated Investors, expanding the availability of Shariah-compliant green investment products and community ownership models could activate their existing positive intentions. For Risk-Averse Traditionalists, government-backed risk mitigation mechanisms and reliability certification programs might address their specific concerns. For Social Influence Responders, visibility-enhancing programs and social norm interventions highlighting adoption trends could leverage their normative sensitivities.

The limitations of this study include its cross-sectional nature, which captures intentions but cannot track actual investment behavior over time. Additionally, the sample's gender imbalance, while reflecting broader financial sector participation patterns in Pakistan, may limit insights regarding female investor perspectives. Future research should employ longitudinal designs to track how intentions translate into actual investment behaviors across segments, and explore intervention effectiveness through controlled trials. Expanding geographic coverage to more rural

regions and developing more balanced gender representation would enhance the comprehensiveness of the segmentation framework.

In conclusion, this study provides a nuanced understanding of Pakistan's renewable energy investment landscape through a psychographic segmentation approach that reveals distinct investor profiles with different barriers, motivations, and product preferences. The identification of ESG-Motivated Investors as the largest segment challenges assumptions about purely financial motivations in emerging market contexts, while the profile of Social Influence Responders highlights untapped opportunities for norm-based interventions. The persistent skepticism of Risk-Averse Traditionalists underscores the continued importance of addressing information asymmetries and risk concerns. These findings collectively suggest that accelerating renewable energy investment in Pakistan requires differentiated strategies targeting specific investor segments rather than uniform approaches, with particular attention to the social and value dimensions of investment decision-making that traditional financial models often underemphasize.

## CONCLUSIONS

This study provides a nuanced understanding of the behavioral drivers influencing renewable energy investment decisions among retail investors in Pakistan. By employing advanced clustering techniques, we identified three distinct investor segments—ESG-Motivated Investors, Risk-Averse Traditionalists, and Social Influence Responders—each characterized by unique psychological, social, and cognitive attributes that shape their investment approaches.

The heterogeneity revealed through this behavioral segmentation underscores the limitations of one-size-fits-all approaches to renewable energy financing. Instead, the findings suggest that effective mobilization of retail investment requires targeted interventions addressing the specific motivations, concerns, and decision-making processes of each investor segment. For ESG-Motivated Investors (36.1%), who demonstrated the strongest environmental values and highest financial literacy, environmental impact verification and Islamic finance alignment represent key priorities, with particular interest in green sukuk (57.2%) and community renewable energy cooperatives (42.1%). Risk-Averse Traditionalists (34.0%), characterized by technological skepticism and conventional investment preferences, require enhanced security mechanisms and familiarity building through demonstration effects that address their specific concerns about reliability and returns. Social Influence Responders (29.9%), who exhibited high susceptibility to peer influence and normative pressures, are most effectively engaged through peer networks, status recognition, and visible participation opportunities, with particular appeal for tangible investments like rooftop solar (58.7%).

Beyond these segment-specific insights, our research highlights several cross-cutting factors shaping Pakistan's renewable energy investment landscape. Financial literacy—particularly regarding renewable energy-specific concepts, emerges as a crucial enabler across all segments, with significant disparities observed between

ESG-Motivated Investors (mean RE-specific knowledge = 3.62/4.00) and other segments. Regulatory complexity and fragmentation continue to create friction, deterring retail participation despite strong underlying interest, as evidenced by the gap between positive attitudes and actual investment behavior (overall only 18.2% reported prior renewable energy investment experience). Digital infrastructure development represents a critical pathway for reducing transaction costs and information asymmetries that currently limit market access, particularly for younger investors in the Social Influence Responders segment who demonstrate strong digital engagement (92.1% reporting daily social media usage).

The policy implications extend beyond traditional financial incentives to encompass a comprehensive ecosystem approach. Tailored tax incentives, risk mitigation instruments, certification standards, social norm campaigns, and technological platforms collectively offer a pathway toward more inclusive renewable energy financing. For financial institutions, significant opportunities exist in developing segment-specific products, innovative distribution channels, and refined communication strategies that resonate with the distinct psychological profiles identified in this research. This is particularly important given the substantial proportion of respondents expressing intention to invest in renewable energy within the next 12 months (68.4% of ESG-Motivated Investors and 49.2% of Social Influence Responders).

As Pakistan pursues its ambitious renewable energy targets amid fiscal constraints and climate imperatives, retail investor participation represents an increasingly critical financing channel. This research contributes to unlocking this potential by providing evidence-based insights into the complex behavioral factors that drive or impede individual investment decisions. Future research should expand on these findings through longitudinal designs that track how intentions translate into actual behaviors, and controlled trials evaluating the effectiveness of segment-specific interventions. Through targeted approaches informed by behavioral science, policymakers and financial institutions can more effectively mobilize the distributed capital required for Pakistan's sustainable energy transition, unlocking new pathways for growth while addressing pressing environmental challenges.

### Abbreviations

The following abbreviations are used in this manuscript:

<b>Abbreviation</b>	<b>Full Form</b>
RE	Renewable Energy
ESG	Environmental, Social, and Governance
MW	Megawatt
GDP	Gross Domestic Product
PKR	Pakistani Rupee
SECP	Securities and Exchange Commission of Pakistan
PBC	Perceived Behavioral Control
TPB	Theory of Planned Behavior

<b>Abbreviation</b>	<b>Full Form</b>
CFI	Comparative Fit Index
RMSEA	Root Mean Square Error of Approximation
SRMR	Standardized Root Mean Square Residual
AVE	Average Variance Extracted
CR	Composite Reliability
KR-20	Kuder-Richardson Formula 20
WCSS	Within-Cluster Sum of Squares
MANOVA	Multivariate Analysis of Variance
ANOVA	Analysis of Variance
HSD	Honestly Significant Difference
REITs	Renewable Energy Investment Trusts

## **Appendix A**

### **Appendix A.1**

The appendix is an optional section that can contain details and data supplemental to the main text—for example, explanations of experimental details that would disrupt the flow of the main text but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data is shown in the main text can be added here if brief, or as Supplementary data. Mathematical proofs of results not central to the paper can be added as an appendix.

**Table A1.** This is a table caption.

### **Appendix B**

<b>Title 1</b>	<b>Title 2</b>	<b>Title 3</b>
entry 1	data	data
entry 2	data	data <sup>1</sup>

All appendix sections must be cited in the main text. In the appendices, Figures, Tables, etc. should be labeled starting with “A”—e.g., Figure A1, Figure A2, etc.

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