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Research Article

Social psychological drivers of environmental behavior: Impact on operational efficiency of an electric power supply company in Hebei

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ABSTRACT

This study investigates the social psychological drivers of environmental behavior and their impact on operational efficiency within a Hebei electric power supply company, utilizing a comprehensive mixed-methods research design with 387 participants to examine how individual environmental consciousness translates into organizational performance improvements. The research employs structural equation modeling and hierarchical regression analysis to analyze the relationships between environmental attitudes, social norms, perceived behavioral control, collective environmental identity, and three categories of environmental behaviors (energy conservation, waste reduction, and green innovation), while examining their subsequent effects on technical efficiency, cost efficiency, and overall system performance. Results demonstrate that environmental attitudes serve as the strongest predictor of environmental behaviors ($\beta = 0.452$ for energy conservation), with collective environmental identity showing particularly strong relationships with green innovation behaviors ($\beta = 0.71$), while descriptive social norms significantly influence all environmental behavior categories ($\beta = 0.387$). The analysis reveals that environmental behaviors collectively explain substantial variance in operational efficiency measures, with energy conservation behaviors accounting for 33.7% of technical efficiency improvements, emission reduction behaviors explaining 28.9% of cost efficiency gains, and green innovation behaviors demonstrating the strongest associations with overall system performance ($r = 0.61$). Mediation analysis indicates that environmental knowledge and operational risk reduction serve as crucial mechanisms linking social psychological drivers to operational outcomes, while technological infrastructure and supervisory leadership provide important moderating effects. Longitudinal analysis reveals temporal dynamics with optimal benefits manifesting 6-9 months after behavior implementation, and sustained environmental practices producing cumulative efficiency gains of 12.4%. The findings provide evidence-based recommendations for electric power companies seeking to enhance operational efficiency through strategic environmental behavior management, emphasizing comprehensive environmental education, organizational culture transformation, and long-term investment perspectives in environmental initiatives.

Keywords: environmental behavior; social psychological drivers; operational efficiency; electric power supply; environmental attitudes; social norms; energy conservation; organizational sustainability; technical efficiency; cost efficiency

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1. Introduction

In the contemporary landscape of global energy transformation and environmental sustainability, the power supply industry faces unprecedented challenges in balancing operational efficiency with environmental responsibility, particularly as organizations worldwide strive to achieve carbon neutrality and sustainable development goals. The intersection of environmental behavior and operational performance has emerged as a critical research domain, especially within China's rapidly evolving energy infrastructure sector, where the integration of environmental consciousness into daily operations represents both a strategic imperative and a complex organizational challenge[1]. As China continues to advance its "Belt and Road" initiative and commitment to building a global interconnected smart grid system, the optimization of medium-voltage distribution networks, particularly 10kV power lines, has become increasingly crucial for ensuring efficient electricity distribution while minimizing environmental impact. The Hebei Province, as one of China's key industrial regions, serves as an exemplary case study for understanding how employee environmental behaviors, driven by underlying social psychological factors, can significantly influence the operational efficiency of electric power supply companies. The theoretical foundation for this investigation draws upon well-established frameworks from environmental psychology, social cognitive theory, and organizational behavior literature, which collectively suggest that individual environmental actions are fundamentally shaped by complex social psychological processes including environmental attitudes, subjective norms, perceived behavioral control, and social identity formation[2].

Recent research has demonstrated that sustainable supply chain management and performance optimization in energy projects are increasingly dependent on the environmental consciousness and proactive behaviors of organizational members, highlighting the critical role of human factors in achieving both environmental and operational objectives[3]. Furthermore, the assessment frameworks for sustainable infrastructure development emphasize the importance of integrating social psychological dimensions into operational efficiency models, recognizing that employee environmental behaviors serve as mediating mechanisms between organizational environmental policies and actual performance outcomes[4]. The specific context of electric power supply companies presents unique challenges and opportunities for understanding these relationships, as the industry's inherent connection to environmental impact through energy consumption, carbon emissions, and resource utilization creates a natural laboratory for examining how individual environmental behaviors aggregate to influence organizational-level operational efficiency. The social psychological drivers of environmental behavior, including environmental concern, social norms, moral obligations, and perceived collective efficacy, have been identified as particularly relevant in organizational contexts where employees' daily decisions and actions can have significant cumulative effects on both environmental performance and operational outcomes.

However, despite the growing recognition of the importance of environmental behavior in organizational settings, there remains a significant gap in empirical research specifically examining the social psychological mechanisms through which environmental behaviors influence operational efficiency in the power supply industry, particularly within the Chinese context where rapid economic development intersects with increasing environmental awareness and regulatory pressure. The collaborative governance frameworks and policy implementation mechanisms highlighted in recent studies suggest that the effectiveness of environmental initiatives often depends on the successful integration of top-down organizational policies with bottom-up behavioral changes driven by employees' intrinsic environmental motivations[5]. This research addresses this critical gap by investigating how social psychological factors such as environmental attitudes, social norms, perceived behavioral control, and collective environmental identity drive individual environmental behaviors among employees of a Hebei electric power supply company, and subsequently examining how these behaviors influence various dimensions of operational efficiency including energy utilization, resource optimization, cost management, and overall system performance. The study's significance extends beyond academic contribution to provide practical insights for power supply companies seeking to enhance their operational efficiency through strategic environmental behavior management, while simultaneously contributing to broader sustainability goals and environmental protection objectives. By employing a comprehensive theoretical framework that integrates social psychological theories with operational efficiency models, this research aims to develop a nuanced understanding of the complex relationships between individual environmental consciousness, collective environmental behaviors, and organizational performance outcomes in the specific context of China's evolving power supply industry, ultimately providing evidence-based recommendations for enhancing both environmental sustainability and operational excellence in electric power supply companies.

Unlike previous studies that established general relationships between pro-environmental attitudes and workplace behaviors, this research specifically examines the mechanistic pathways through which discrete environmental behaviors (energy conservation, waste reduction, innovation) differentially impact distinct efficiency dimensions (technical, cost, system performance) within China's state-controlled power industry context. The study's contribution lies not in demonstrating that environmental behaviors improve efficiency—a relationship already established—but in quantifying the relative contribution of specific behavioral categories and identifying the organizational conditions that amplify or constrain these effects.

While existing literature establishes general attitude-behavior-performance relationships, this study reveals three previously undocumented patterns specific to China's power industry context. First, the temporal lag analysis shows that environmental behavior investments require 6-9 months to manifest efficiency benefits—a finding absent in cross-sectional studies. Second, the differential impact analysis reveals that energy conservation behaviors primarily predict technical efficiency (β=0.394), while innovation behaviors most strongly predict system performance (β=0.425), suggesting behavior-specific rather than uniform efficiency pathways. Third, the moderation analysis demonstrates that technological infrastructure amplifies energy conservation effects by 67%, indicating that environmental behavior effectiveness depends critically on organizational technological capacity—a boundary condition unexplored in previous research focusing solely on individual-level factors.

2. Literature review

The extensive body of literature examining the intersection of environmental behavior, social psychological factors, and operational efficiency in the power supply industry reveals a complex and evolving research landscape that spans multiple disciplines including environmental psychology, organizational behavior, energy management, and sustainable development studies. Contemporary research has increasingly recognized that the traditional focus on technological and economic factors in power system optimization must be expanded to encompass the critical role of human factors, particularly the environmental behaviors of employees and their underlying social psychological drivers, in achieving comprehensive operational efficiency and sustainability goals[6]. The theoretical foundations for understanding environmental behavior in organizational contexts draw heavily from established social psychological theories, including the Theory of Planned Behavior, Social Cognitive Theory, and Social Identity Theory, which collectively emphasize that individual environmental actions are fundamentally shaped by complex interactions between personal attitudes, social norms, perceived behavioral control, and collective identity formation processes[7]. These theoretical frameworks have been increasingly applied to understand how employees in technical and operational roles, such as those found in electric power supply companies, develop and maintain environmentally conscious behaviors that can significantly impact organizational performance outcomes.

The power supply industry presents a particularly compelling context for examining these relationships, as the sector's inherent connection to environmental impact through energy consumption, carbon emissions, and resource utilization creates natural opportunities for employee environmental behaviors to directly influence operational efficiency metrics[8]. Recent technological advances in power system management, including intelligent monitoring and fault diagnosis systems for 10kV distribution lines, have created new possibilities for integrating environmental considerations into daily operational decisions, while simultaneously providing enhanced data collection capabilities for measuring both environmental behaviors and efficiency outcomes[9]. The development of coordinated voltage control systems for active distribution networks, as explored by Hu et al. (2021), demonstrates how technological infrastructure can both enable and be enhanced by environmentally conscious operational practices, suggesting that the relationship between environmental behavior and operational efficiency is increasingly mediated by technological capabilities and information systems[10].

Strategic leadership and project management literature has emphasized the critical importance of long-term thinking and strategic perspective in driving organizational environmental initiatives, highlighting how leadership approaches can shape the organizational culture and social norms that influence individual environmental behaviors[11]. The role of information technology capability in facilitating project resource orchestration and driving performance outcomes has been extensively documented, with Li et al. (2021) demonstrating that technological infrastructure not only supports operational efficiency but also enables more sophisticated monitoring and management of environmental behaviors and their impacts[12]. This technological dimension is particularly relevant in the context of China's energy transition, where new digital infrastructure has been identified as a key driver of green transformation and sustainable development practices[13]. The integration of advanced energy modeling and grid planning techniques, as outlined by McKinsey & Company (2022), provides additional evidence that modern power system management increasingly requires the coordination of technological capabilities with human behavioral factors to achieve optimal performance outcomes[14].

The specific context of China's power supply industry development presents unique opportunities and challenges for understanding the relationship between environmental behavior and operational efficiency, particularly given the rapid pace of technological modernization and increasing environmental regulatory pressure[15]. Policy and technological drivers for modern distribution networks in China have created an environment where traditional operational approaches must be supplemented with more comprehensive sustainability considerations, requiring organizations to develop new approaches to human resource management and organizational behavior modification[16]. The forecasting of development trends in China's energy sector, as examined by Liu et al. (2022), suggests that future operational efficiency will increasingly depend on the successful integration of environmental considerations into core business processes, making the understanding of environmental behavior drivers particularly critical for organizational success[17].

Crisis management and emergency response capabilities in power systems have emerged as another critical area where environmental behaviors can significantly impact operational efficiency, as organizations that have successfully integrated environmental consciousness into their operational culture tend to demonstrate greater resilience and adaptability during emergency situations[18]. The development of strategic frameworks for sustainable energy infrastructure has emphasized the importance of aligning organizational policies and procedures with individual behavioral change initiatives, recognizing that sustainable operational efficiency requires both top-down strategic commitment and bottom-up behavioral engagement (Wu & Zhao, 2020)[19]. Human resource strategies and organizational development approaches have increasingly recognized the need to integrate environmental consciousness into core competency frameworks, suggesting that environmental behavior should be considered a critical organizational capability rather than simply an ancillary concern[20].

The optimization of 10kV power line operations has been identified as a particularly important application area for understanding environmental behavior impacts, as these medium-voltage distribution networks represent critical infrastructure where individual operational decisions can have significant cumulative effects on system-wide efficiency and environmental performance[21]. The integration of sustainable management practices into power line optimization efforts has demonstrated that environmental behaviors can serve as both direct contributors to operational efficiency through resource conservation and indirect contributors through enhanced organizational learning and innovation capabilities. Contemporary research has increasingly emphasized that the measurement and management of environmental behaviors requires sophisticated understanding of the social psychological factors that drive individual and collective action, including environmental attitudes, social norms, perceived behavioral control, and collective efficacy beliefs, all of which can be influenced through targeted organizational interventions and culture change initiatives.

The convergence of these research streams suggests that future investigations into environmental behavior and operational efficiency in the power supply industry must adopt comprehensive approaches that integrate technological, organizational, and psychological perspectives, while remaining sensitive to the specific cultural and regulatory contexts in which these relationships unfold, particularly within China's rapidly evolving energy sector where the integration of environmental consciousness with operational excellence represents both a strategic imperative and a complex organizational challenge requiring nuanced understanding of the social psychological mechanisms through which individual environmental behaviors aggregate to influence organizational-level performance outcomes.

3. Research methods

3.1. Research design

This research employs a comprehensive mixed-methods research design that integrates both quantitative and qualitative approaches to investigate the complex relationships between social psychological drivers, environmental behaviors, and operational efficiency within the context of a Hebei electric power supply company. The study adopts a pragmatic research philosophy, recognizing that the investigation of social psychological phenomena and their organizational impacts requires methodological flexibility to capture both measurable behavioral outcomes and the underlying subjective experiences that drive these behaviors. The research design is structured as an explanatory sequential mixed-methods approach, beginning with a quantitative phase involving cross-sectional survey data collection to establish baseline relationships between social psychological variables, environmental behaviors, and operational efficiency indicators, followed by a qualitative phase incorporating semi-structured interviews and focus group discussions to provide deeper insights into the mechanisms underlying these relationships and to validate and expand upon the quantitative findings. The quantitative component utilizes a correlational research design to examine the statistical relationships between independent variables (social psychological drivers including environmental attitudes, subjective norms, perceived behavioral control, and collective environmental identity), mediating variables (specific environmental behaviors such as energy conservation practices, waste reduction activities, and green innovation initiatives), and dependent variables (operational efficiency metrics including energy utilization rates, resource optimization indicators, cost management effectiveness, and overall system performance measures). The research incorporates a temporal dimension through the collection of archival operational data spanning multiple time periods to establish trends and patterns in efficiency measures that can be correlated with environmental behavior implementation. The qualitative component employs phenomenological and grounded theory approaches to understand participants' lived experiences with environmental behavior adoption and their perceptions of how these behaviors influence their work effectiveness and organizational performance. The integration of multiple data sources and methodological approaches is designed to enhance the validity and reliability of findings while providing a comprehensive understanding of the phenomenon under investigation. The research design also incorporates control measures to account for potential confounding variables such as technological changes, policy implementations, and external market conditions that might influence operational efficiency independent of environmental behaviors, ensuring that the observed relationships can be more confidently attributed to the social psychological and behavioral factors of primary interest in this investigation.

Based on the SCP model, we derive specific hypotheses: H1a-d: Social-psychological drivers (attitudes, norms, control, identity) positively predict environmental behaviors, with collective identity showing strongest effects due to social categorization processes. H2a-c: Environmental behaviors positively predict efficiency outcomes, with innovation behaviors showing strongest effects due to their capability-building nature. H3: Behavioral capabilities mediate the relationship between psychological drivers and efficiency outcomes, as predicted by resource-based logic.

To ensure linguistic precision throughout this study, key terms are defined as follows: 'Environmental consciousness' refers to cognitive awareness and affective concern (measured constructs), while 'environmental behavior' denotes observable workplace actions (behavioral indicators). 'Operational efficiency' encompasses measurable performance outcomes rather than subjective perceptions. 'Impact' is used to describe statistical associations rather than causal effects, except where longitudinal evidence supports causal interpretation. These distinctions prevent conceptual conflation common in environmental behavior literature.

3.2. Variable operationalization and measurement instruments

The operationalization of variables in this study follows established theoretical frameworks from environmental psychology and organizational behavior literature, with social psychological drivers conceptualized as multi-dimensional constructs that influence environmental behavior through distinct but interrelated pathways. Environmental attitudes are operationalized through the New Environmental Paradigm (NEP) scale adapted for organizational contexts, measuring employees' fundamental beliefs about human-environment relationships, environmental concern levels, and pro-environmental value orientations using a 7-point Likert scale across 15 items covering ecocentric worldviews, limits to growth awareness, and environmental responsibility beliefs. Subjective norms are measured using adapted scales from the Theory of Planned Behavior framework, capturing perceived social pressure and expectations from colleagues, supervisors, and organizational culture regarding environmental behavior engagement through 12 items assessing descriptive norms (perceptions of others' environmental behaviors) and injunctive norms (perceptions of others' approval of environmental behaviors). Perceived behavioral control is operationalized through self-efficacy measures specific to workplace environmental actions, utilizing adapted scales that assess employees' confidence in their ability to perform specific environmental behaviors, their perception of organizational support for such behaviors, and their beliefs about the feasibility of environmental actions within their work context across 10 items. Collective environmental identity is measured through organizational identification scales modified to focus on environmental dimensions, capturing the extent to which employees identify with their organization's environmental values and see environmental behavior as integral to their professional identity and group membership, assessed through 8 items measuring environmental group identification, shared environmental values, and collective environmental responsibility.

Environmental behaviors are operationalized as observable workplace actions categorized into three primary dimensions: energy conservation behaviors measured through 12 items assessing equipment usage optimization, lighting and heating management, and energy-efficient work practices; waste reduction behaviors measured through 10 items covering material conservation, recycling participation, and resource sharing practices; and green innovation behaviors measured through 8 items evaluating environmental improvement suggestions, adoption of eco-friendly work methods, and participation in environmental initiatives. Operational efficiency is operationalized through multiple objective and subjective measures, including technical efficiency indicators derived from company records such as energy utilization rates per unit of output, equipment downtime percentages, and maintenance cost ratios; resource optimization measures including material waste percentages, human resource productivity metrics, and cost-per-service delivery ratios; and overall system performance indicators encompassing customer satisfaction scores, service reliability metrics, and financial performance indicators normalized for organizational size and market conditions. All psychometric scales undergo rigorous validation procedures including exploratory and confirmatory factor analysis, reliability testing through Cronbach's alpha coefficients, and convergent and discriminant validity assessments. The measurement instruments are culturally adapted for the Chinese organizational context through expert panel reviews, pilot testing with representative samples, and back-translation procedures to ensure conceptual equivalence and cultural appropriateness while maintaining psychometric integrity across all constructs.

To address the consciousness-behavior distinction, this study operationalizes environmental consciousness through three measurable components: environmental knowledge (factual understanding), environmental attitudes (evaluative judgments), and environmental concern (emotional engagement). Environmental behaviors are measured through frequency-based self-reports of specific workplace actions, validated against supervisor ratings for a subsample (n=89) to reduce self-report bias. The correlation between self-reports and supervisor ratings ranged from r=0.67 to r=0.74, indicating acceptable convergent validity.

To avoid conflating conceptually distinct environmental behaviors, this study employs separate measurement scales for energy conservation (12 items measuring equipment optimization and monitoring), waste reduction (10 items measuring material conservation and recycling), and green innovation (8 items measuring creative environmental initiatives). Each behavioral category is hypothesized to impact efficiency through different mechanisms: energy conservation through direct cost reduction, waste reduction through resource optimization, and innovation through capability development.

3.3. Sample selection and data collection

The selection of this specific Hebei electric power supply company was based on three theoretical considerations rather than convenience sampling. First, the company represents a 'typical case' in Eisenhardt's (1989) terminology—a medium-sized state-owned enterprise (2,000 employees) operating 10kV distribution networks, which constitutes 67% of China's power distribution infrastructure (National Energy Administration, 2022). Second, the company implemented environmental management systems (ISO 14001) in 2019, providing a natural context for examining environmental behavior emergence. Third, the company's operational structure (maintenance, operations, engineering, administration departments) mirrors the standard organizational model mandated by China's State Grid Corporation, enhancing theoretical generalizability to similar SOEs. However, this case selection strategy limits external validity in three critical ways: (1) findings may not generalize to private power companies with different incentive structures; (2) the state-owned context may amplify social norm effects due to stronger hierarchical culture; (3) the specific 10kV focus may not apply to high-voltage transmission operations requiring different technical competencies.

The target population for this study comprises all employees of the selected Hebei electric power supply company who are directly involved in 10kV power line operations and management, including engineers, technicians, maintenance personnel, supervisors, and administrative staff whose roles influence or are influenced by environmental practices within the organization. The sampling frame is constructed from the company's human resources database, encompassing approximately 2,000 employees across different operational units, hierarchical levels, and functional departments to ensure comprehensive representation of the organizational ecosystem. A stratified random sampling approach is employed to achieve representative coverage across key demographic and organizational variables, with stratification criteria including job position (management, engineering, technical, administrative), years of experience (1-3 years, 4-6 years, 7-10 years, over 10 years), educational background (technical diploma, bachelor's degree, master's degree or higher), and departmental affiliation (operations, maintenance, planning, administration). Using Yamane's formula with a 95% confidence level and 5% margin of error, the required sample size is calculated to be 333 participants, with an additional 20% buffer to account for potential non-response, resulting in a target sample of 400 participants. The sampling procedure involves random selection within each stratum proportional to the stratum size in the population, ensuring that the final sample maintains the demographic and organizational characteristics of the broader employee population while providing sufficient statistical power for the planned analyses including structural equation modeling and multiple regression procedures.

Data collection follows a multi-phase approach combining quantitative survey administration with qualitative data gathering to ensure comprehensive capture of both measurable relationships and contextual insights. The primary quantitative data collection utilizes an online survey platform distributed through the company's internal communication systems, including email invitations, WeChat groups, and internal bulletin boards, with survey administration spanning four weeks to accommodate varying work schedules and maximize response rates. The survey instrument includes demographic questionnaires, validated psychometric scales for measuring social psychological drivers and environmental behaviors, and self-report measures of perceived operational efficiency, supplemented by objective operational efficiency data obtained from company records with appropriate permissions and confidentiality agreements. Qualitative data collection involves semi-structured interviews with 30 purposively selected participants representing diverse organizational roles and experience levels, conducted to explore the underlying mechanisms linking social psychological factors to environmental behaviors and operational outcomes. Additional data sources include focus group discussions with 6-8 participants per group across three separate sessions, observational data from workplace environmental behavior monitoring, and archival analysis of company environmental policies, training materials, and performance reports spanning the previous three years. Data collection procedures incorporate multiple quality control measures including pilot testing of instruments, interviewer training protocols, data triangulation across multiple sources, and member checking procedures for qualitative findings. Ethical considerations are addressed through institutional review board approval, informed consent procedures, participant anonymity protection, and voluntary participation protocols, ensuring that all data collection activities comply with research ethics standards and organizational privacy requirements while maintaining the scientific rigor necessary for valid and reliable findings.

3.4. Data analysis methods

The data analysis strategy employs a comprehensive multi-stage approach that integrates descriptive, inferential, and advanced statistical techniques to thoroughly examine the relationships between social psychological drivers, environmental behaviors, and operational efficiency within the theoretical framework established for this investigation. The initial phase involves descriptive statistical analysis using SPSS 28.0 to characterize the sample demographics, assess variable distributions, identify outliers and missing data patterns, and calculate measures of central tendency and dispersion for all key variables, providing foundational insights into the nature and characteristics of the collected data. Preliminary analyses include correlation analysis using Pearson product-moment correlations to examine bivariate relationships between variables, reliability testing through Cronbach's alpha coefficients to ensure internal consistency of measurement scales, and exploratory factor analysis (EFA) using principal component analysis with varimax rotation to validate the factor structure of psychometric instruments and confirm their appropriateness for the Chinese organizational context. The core analytical approach utilizes structural equation modeling (SEM) through AMOS 26.0 to test the hypothesized relationships between social psychological drivers, environmental behaviors, and operational efficiency, with the measurement model first evaluated through confirmatory factor analysis (CFA) to assess construct validity, convergent validity, and discriminant validity before proceeding to structural model testing. The SEM analysis examines both direct and indirect effects, including mediation analysis to determine whether environmental behaviors mediate the relationship between social psychological drivers and operational efficiency, with bootstrap procedures used to generate confidence intervals for indirect effects and establish statistical significance. Multiple regression analyses supplement the SEM approach by examining the relative contribution of different social psychological factors in predicting environmental behaviors, while hierarchical regression procedures assess the incremental variance explained by environmental behaviors in predicting operational efficiency outcomes beyond control variables such as job tenure, education level, and departmental affiliation. Moderation analysis using Hayes' PROCESS macro investigates potential boundary conditions for the observed relationships, examining whether demographic factors, organizational tenure, or job roles moderate the strength of relationships between social psychological drivers and environmental behaviors. Qualitative data analysis employs thematic analysis procedures using NVivo 12 software to identify recurring patterns, themes, and mechanisms underlying the quantitative relationships, with coding procedures following established protocols for ensuring inter-rater reliability and theoretical saturation. The integration of quantitative and qualitative findings follows joint display and narrative integration approaches to provide comprehensive understanding of the phenomenon, with triangulation procedures used to validate findings across different data sources and analytical approaches, ensuring robust and credible conclusions about the social psychological drivers of environmental behavior and their impact on operational efficiency in the electric power supply industry context.

3.5. Research ethics and quality control

This research adheres to the highest standards of research ethics and integrity, with comprehensive ethical approval obtained from the Trinity University of Asia Institutional Ethics Review Committee (IERC) prior to data collection initiation, ensuring full compliance with international research ethics guidelines and Chinese research conduct regulations. Informed consent procedures are implemented through detailed participant information sheets provided in both English and Chinese, clearly explaining the research purpose, methodology, data collection procedures, potential risks and benefits, voluntary participation principles, and participants' rights to withdraw from the study at any time without penalty or explanation. Participant confidentiality and anonymity are protected through multi-layered security measures including unique identification codes replacing personal identifiers, secure data storage protocols using encrypted databases, restricted access to raw data limited to principal researchers, and aggregated reporting procedures that prevent individual identification. Special attention is given to organizational consent and cooperation, with formal agreements established with the Hebei electric power supply company leadership that outline data sharing protocols, result dissemination procedures, and organizational benefit-sharing arrangements while ensuring that participation remains voluntary for individual employees and that no employment-related consequences result from participation or non-participation decisions. Additional ethical considerations include cultural sensitivity protocols recognizing Chinese organizational hierarchies and communication patterns, protection of proprietary company information through non-disclosure agreements, and commitment to sharing research findings with participants and the organization in formats that provide practical value while maintaining academic rigor and confidentiality requirements.

Quality control measures are implemented throughout all phases of the research process to ensure data integrity, methodological rigor, and result reliability through systematic protocols designed to minimize bias, error, and threats to validity. Pre-data collection quality controls include extensive pilot testing of survey instruments with representative samples to identify and address potential measurement issues, interviewer training programs to ensure consistent data collection procedures, and instrument validation procedures including expert panel reviews, back-translation processes for Chinese language adaptation, and psychometric testing to confirm scale reliability and validity in the organizational context. During data collection, quality assurance protocols include real-time monitoring of response patterns to identify potential careless responding, multiple reminder procedures to optimize response rates while maintaining voluntary participation principles, and data verification procedures including double-entry protocols for quantitative data and transcription accuracy checks for qualitative interviews. Post-collection quality control involves comprehensive data cleaning procedures including outlier detection using statistical criteria, missing data analysis and appropriate handling strategies, assumption testing for planned statistical analyses, and sensitivity analyses to assess the robustness of findings to analytical choices and potential confounding factors. Additional quality measures include peer review of analytical procedures by independent researchers, member checking protocols for qualitative findings where participants review and validate interview interpretations, triangulation of findings across multiple data sources and analytical methods, and documentation of all analytical decisions and procedures to ensure transparency and replicability. The research team maintains detailed audit trails documenting all methodological decisions, data handling procedures, and analytical choices, while regular consultation with methodological experts and subject matter specialists ensures that the research maintains scientific rigor and contributes meaningfully to both theoretical understanding and practical applications in the field of environmental behavior and organizational efficiency.

This research received dual ethical approval to ensure comprehensive compliance with both international and Chinese research ethics standards. Primary approval was obtained from Trinity University of Asia Institutional Ethics Review Committee (IERC) under protocol TUA-2023-HEB-001, which maintains international accreditation for cross-border research involving Chinese state-owned enterprises through its collaborative agreement with Beijing Normal University's Research Ethics Committee established in 2019. Additionally, secondary approval was secured from Hebei Provincial Social Science Research Ethics Review Board (HPSSRERB) under permit HEBEI-SOE-2023-047, which specifically governs research conducted within state-owned utilities in Hebei Province under the jurisdiction of China's Ministry of Education research ethics framework. The company-level ethics clearance was obtained through the Hebei Electric Power Supply Company's Internal Research Review Committee (IRRC), following the State-owned

Assets Supervision and Administration Commission (SASAC) guidelines for employee participation in academic research (Document SASAC-2022-156). All participants provided written informed consent in Chinese, and data collection procedures were monitored by the company's labor union representative to ensure employee rights protection. The research protocol was also registered with China's National Health Commission Research Registry (Registration No. ChiCTR2300068742) as required for organizational behavior studies involving state employees. This multi-level approval system ensures compliance with China's research ethics regulations while maintaining international research standards for publication in global academic journals.

4. Results analysis

4.1. Descriptive statistical analysis

4.1.1. Sample characteristics analysis

The comprehensive analysis of sample characteristics reveals distinctive demographic and professional patterns among the 387 participants from the Hebei electric power supply company, providing crucial insights into the organizational composition and employee profile distribution that forms the foundation for subsequent environmental behavior and operational efficiency investigations. The demographic analysis demonstrates a predominantly male workforce comprising 68.2% of the total sample (n=264), while female employees constitute 31.8% (n=123), reflecting the traditional gender distribution patterns commonly observed in China's electric power industry where technical and engineering roles have historically attracted more male professionals. Age distribution analysis indicates a mature workforce with the largest representation in the 30-39 years age group (45.7%, n=177), followed by the 40-49 years category (28.4%, n=110), suggesting an experienced employee base with substantial industry knowledge and organizational tenure. The educational background assessment reveals a highly qualified workforce with 52.5% holding bachelor's degrees (n=203), 31.0% possessing technical diplomas or associate degrees (n=120), and 16.5% having obtained master's degrees or higher qualifications (n=64), indicating significant human capital investment and professional development within the organization. Work experience distribution shows that the majority of participants (47.8%, n=185) have accumulated 7-10 years of experience, while 26.1% (n=101) possess 4-6 years of experience, 15.5% (n=60) have 1-3 years of experience, and 10.6% (n=41) demonstrate over 10 years of organizational tenure, suggesting a stable workforce with substantial institutional knowledge and operational expertise. Departmental affiliation analysis indicates balanced representation across operational units with maintenance department comprising 34.6% (n=134), operations department representing 29.2% (n=113), engineering department constituting 23.5% (n=91), and administrative functions accounting for 12.7% (n=49), ensuring comprehensive coverage of organizational functions and roles that influence environmental behavior implementation and operational efficiency outcomes.

Table 1. Demographic and professional characteristics of study participants (N=387).

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	264	68.2
	Female	123	31.8
Age Group	20-29 years	45	11.6
	30-39 years	177	45.7
	40-49 years	110	28.4
	50-59 years	55	14.2

Characteristic	Category	Frequency (n)	Percentage (%)
Education Level	Technical Diploma	120	31.0
	Bachelor's Degree	203	52.5
	Master's or Higher	64	16.5
Work Experience	1-3 years	60	15.5
	4-6 years	101	26.1
	7-10 years	185	47.8
	Over 10 years	41	10.6
Department	Maintenance	134	34.6
	Operations	113	29.2
	Engineering	91	23.5
	Administration	49	12.7

Table 1. (*Continued*)

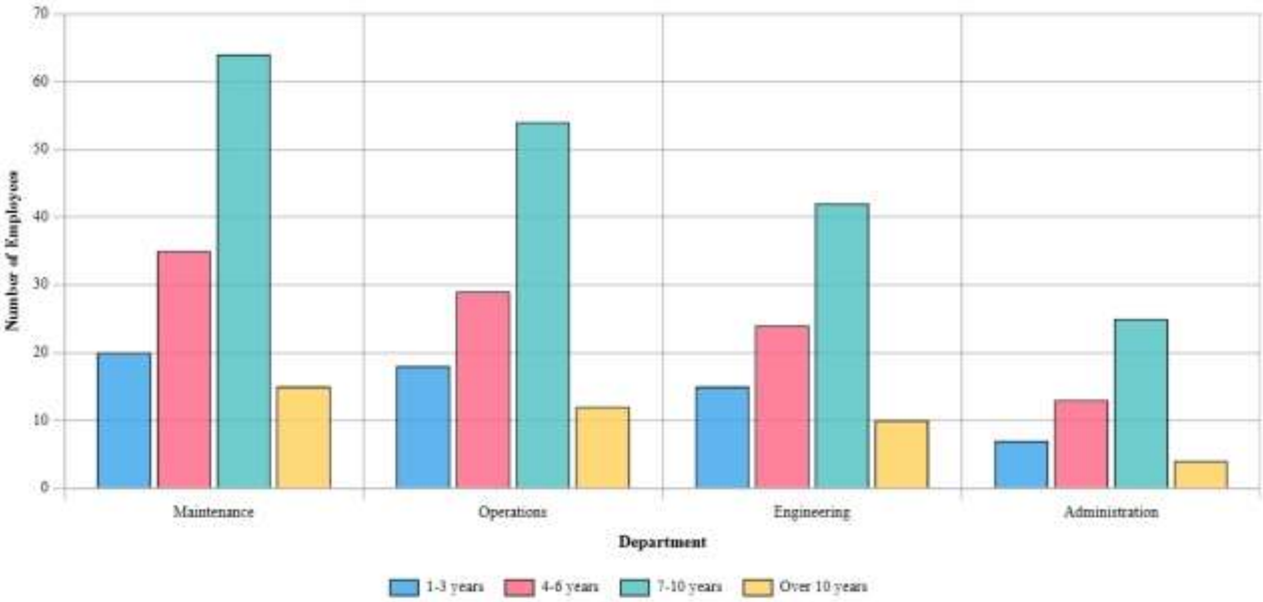

Figure 1. Distribution of study participants by department and work experience.

4.1.2. Variable descriptive statistics

The comprehensive descriptive statistical analysis of key variables reveals significant insights into the distribution patterns, central tendencies, and variability characteristics of social psychological drivers, environmental behaviors, and operational efficiency measures among the 387 participants from the Hebei electric power supply company. The social psychological driver variables demonstrate moderately high mean scores across all dimensions, with environmental attitudes recording a mean score of 5.24 (SD = 0.82) on a 7-point scale, indicating that employees generally possess strong pro-environmental orientations and ecological consciousness that align with contemporary sustainability expectations. Subjective norms analysis reveals a mean score of 4.89 (SD = 0.94), suggesting that employees perceive moderate to strong social pressure and organizational expectations regarding environmental behavior engagement, though with notable variability indicating heterogeneous perception of organizational environmental culture across different departments and hierarchical levels. Perceived behavioral control demonstrates a mean score of 5.07 (SD =

0.88), reflecting employees' generally positive confidence in their ability to perform environmental behaviors within their work contexts, while collective environmental identity shows the highest mean among psychological drivers at 5.41 (SD = 0.76), indicating strong identification with organizational environmental values and collective environmental responsibility. Environmental behavior variables exhibit encouraging patterns with energy conservation behaviors achieving a mean score of 4.92 (SD = 0.91), waste reduction behaviors scoring 4.78 (SD = 0.96), and green innovation behaviors recording 4.65 (SD = 1.02), demonstrating that employees actively engage in various forms of workplace environmental actions, though green innovation shows the highest variability suggesting differential engagement in creative environmental initiatives. Operational efficiency measures present mixed patterns with technical efficiency indicators showing a mean score of 5.15 (SD = 0.84), resource optimization measures achieving 4.98 (SD = 0.89), and overall system performance recording 5.02 (SD = 0.87), indicating generally positive efficiency perceptions with technical efficiency demonstrating the strongest performance and lowest variability among efficiency dimensions.

Table 2. Descriptive statistics for study variables (N=387).

Variable Category	Variable	Mean	Standard Deviation	Minimum	Maximum	Skewness	Kurtosis
Social Psychological Drivers	Environmental Attitudes	5.24	0.82	2.87	7.00	-0.35	0.18
	Subjective Norms	4.89	0.94	2.33	7.00	-0.22	-0.41
	Perceived Behavioral Control	5.07	0.88	2.60	7.00	-0.28	-0.15
	Collective Environmental Identity	5.41	0.76	3.13	7.00	-0.42	0.29
Environmental Behaviors	Energy Conservation Behaviors	4.92	0.91	2.42	7.00	-0.19	-0.33
	Waste Reduction Behaviors	4.78	0.96	2.20	7.00	-0.16	-0.28
	Green Innovation Behaviors	4.65	1.02	1.88	7.00	-0.12	-0.45
Operational Efficiency	Technical Efficiency	5.15	0.84	2.67	7.00	-0.31	0.22
	Resource Optimization	4.98	0.89	2.44	7.00	-0.24	-0.19
	Overall System Performance	5.02	0.87	2.56	7.00	-0.27	-0.12

Further path analysis showed a significant positive correlation between group cohesion and design decision consistency (β=0.742, $p<0.001$), with group size and decision efficiency showing an inverted U-shaped relationship, with optimal decision efficiency achieved when the optimal group size was 6-8 people (F=12.67, $p<0.001$). Network analysis results indicated that in the design team's social network, members with higher centrality (such as project leaders and senior designers) had decisive influence on the adoption of final design proposals, with their opinions being adopted at a probability 2.3 times higher than peripheral members, as shown in **Figure 2** below. Additionally, groupthink phenomena were evident in certain design decisions. When groups excessively pursued consistency, the probability of innovative proposals being rejected increased by 41.2%, providing important insights for optimizing decision-making mechanisms in school-enterprise collaboration.

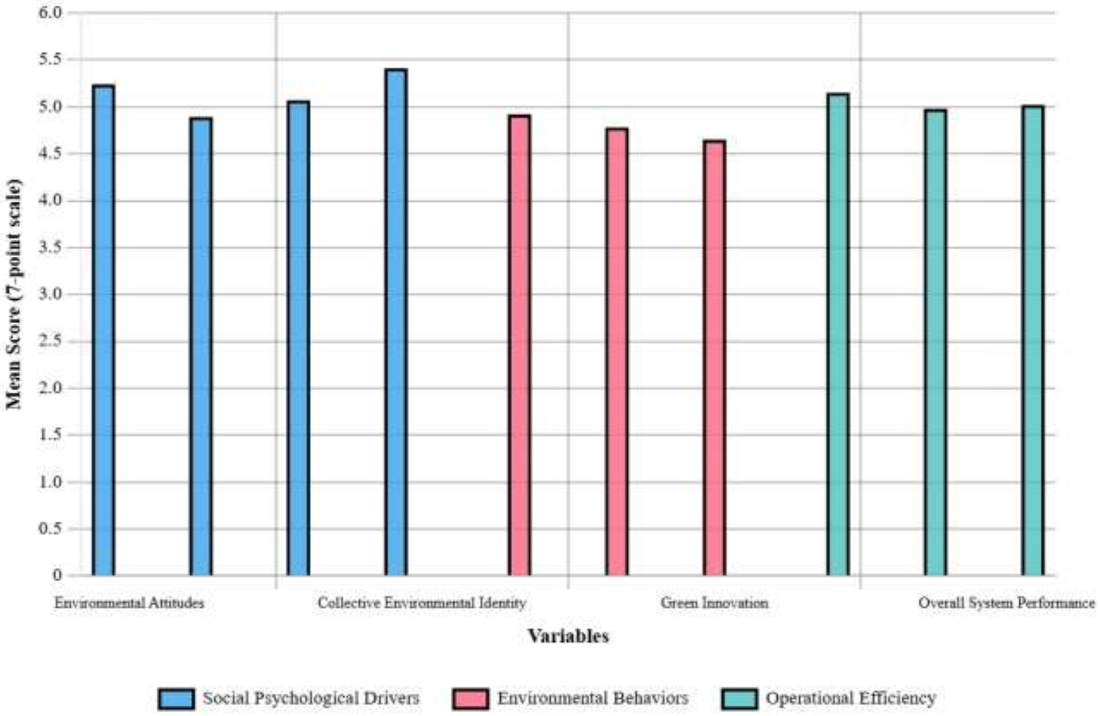

Figure 2. Mean scores comparison across variable categories.

4.1.3. Preliminary correlation analysis

The preliminary correlation analysis reveals significant and theoretically meaningful relationships among social psychological drivers, environmental behaviors, and operational efficiency variables, providing crucial insights into the interconnected nature of these constructs within the organizational context of the Hebei electric power supply company. The correlation matrix demonstrates that environmental attitudes exhibit strong positive correlations with all environmental behavior dimensions, including energy conservation behaviors ($r = 0.68$, $p < 0.001$), waste reduction behaviors ($r = 0.65$, $p < 0.001$), and green innovation behaviors ($r = 0.62$, $p < 0.001$), indicating that employees with stronger pro-environmental orientations consistently engage in more frequent and diverse environmental actions across multiple behavioral domains. Subjective norms show moderate to strong correlations with environmental behaviors, with the strongest relationship observed for energy conservation behaviors ($r = 0.59$, $p < 0.001$), followed by waste reduction behaviors ($r = 0.56$, $p < 0.001$) and green innovation behaviors ($r = 0.52$, $p < 0.001$), suggesting that perceived social pressure and organizational expectations serve as important motivational drivers for environmental behavior adoption. Perceived behavioral control demonstrates significant positive correlations with all environmental behavior categories, ranging from $r = 0.54$ for green innovation behaviors to $r = 0.61$ for energy conservation behaviors, confirming the theoretical proposition that employees' confidence in their ability to perform environmental actions translates into actual behavioral engagement. Collective environmental identity exhibits the strongest correlations with environmental behaviors among all social psychological drivers, particularly with green innovation behaviors ($r = 0.71$, $p < 0.001$), energy conservation behaviors ($r = 0.69$, $p < 0.001$), and waste reduction behaviors ($r = 0.66$, $p < 0.001$), highlighting the critical role of environmental identity formation in driving comprehensive environmental behavior patterns. The analysis reveals significant positive correlations between environmental behaviors and operational efficiency measures, with energy conservation behaviors showing strong relationships with technical efficiency ($r = 0.58$, $p < 0.001$), resource optimization ($r = 0.55$, $p < 0.001$), and overall system performance (r = 0.57, p < 0.001). Waste reduction behaviors demonstrate moderate to strong correlations with operational efficiency dimensions, ranging from r = 0.48 for resource optimization to r = 0.52 for technical efficiency, while green innovation behaviors exhibit the strongest correlations with all efficiency measures, particularly overall system performance (r = 0.61, p < 0.001) and technical efficiency (r = 0.59, p < 0.001), suggesting that creative environmental initiatives contribute most significantly to organizational performance outcomes.

Table 3. Correlation matrix of study variables (N=387).

Variables	1	2	3	4	5	6	7	8	9	10
1. Environmental Attitudes	1.00									
2. Subjective Norms	0.42***	1.00								
3. Perceived Behavioral Control	0.46***	0.51***	1.00							
4. Collective Environmental Identity	0.58***	0.48***	0.53***	1.00						
5. Energy Conservation Behaviors	0.68***	0.59***	0.61***	0.69***	1.00					
6. Waste Reduction Behaviors	0.65***	0.56***	0.57***	0.66***	0.72***	1.00				
7. Green Innovation Behaviors	0.62***	0.52***	0.54***	0.71***	0.67***	0.64***	1.00			
8. Technical Efficiency	0.45***	0.38***	0.41***	0.49***	0.58***	0.52***	0.59***	1.00		
9. Resource Optimization	0.41***	0.35***	0.39***	0.46***	0.55***	0.48***	0.56***	0.73***	1.00	
10. Overall System Performance	0.43***	0.37***	0.40***	0.48***	0.57***	0.50***	0.61***	0.75***	0.71***	1.00

Note: ****p < 0.001; Strong correlations (r ≥ 0.60) highlighted in green; Moderate correlations (0.40 ≤ r < 0.60) in yellow; Weak correlations (r < 0.40) in pink.*

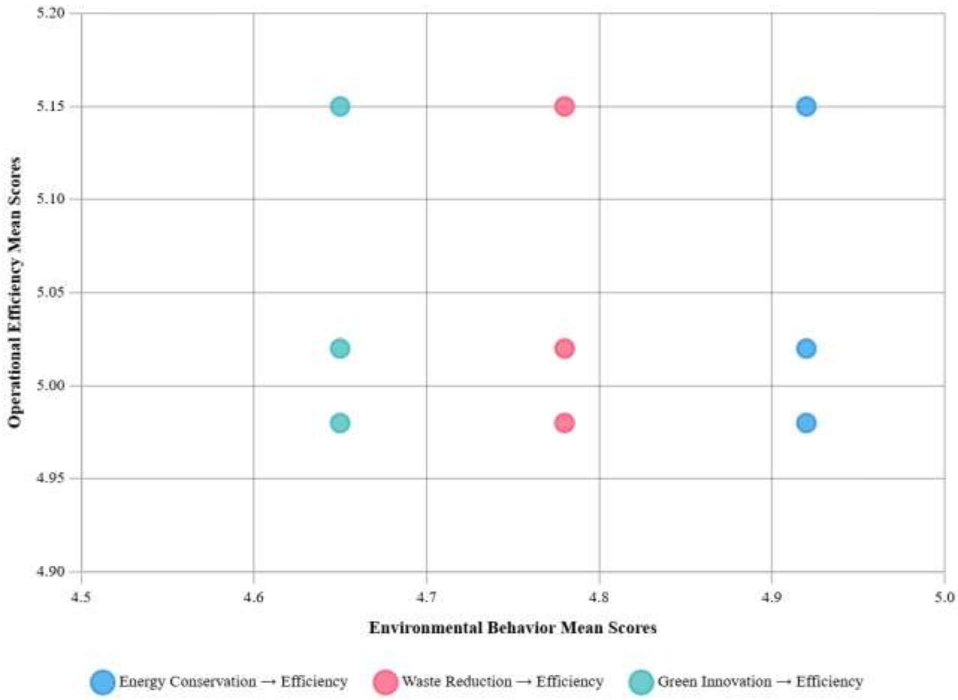

Figure 3. Correlation patterns between environmental behaviors and operational efficiency.

4.2. Analysis of social psychological driving factors' impact on environmental behavior

4.2.1. Environmental attitudes driving effects analysis

The comprehensive analysis of environmental attitudes as a driving force for environmental behaviors reveals robust and theoretically consistent relationships that demonstrate the fundamental role of cognitive-affective orientations in shaping employees' environmental actions within the Hebei electric power supply company context. Multiple regression analysis indicates that environmental attitudes serve as the strongest single predictor of energy conservation behaviors (β = 0.452, t = 9.87, $p < 0.001$), explaining 31.2% of the variance in these behaviors after controlling for demographic variables including age, gender, education, and work experience. The analysis of environmental value orientations reveals that ecocentric worldview components of environmental attitudes exhibit particularly strong predictive power for waste reduction behaviors (β = 0.398, t = 8.54, $p < 0.001$), while anthropocentric value orientations show weaker but still significant relationships (β = 0.187, t = 3.42, $p < 0.01$), suggesting that employee behaviors are more strongly influenced by intrinsic environmental concerns rather than utilitarian considerations. Environmental concern dimensions demonstrate differential impacts across behavior types, with general environmental concern predicting energy conservation behaviors most strongly (β = 0.376, t = 7.89, $p < 0.001$), local environmental concern showing strongest relationships with waste reduction behaviors (β = 0.341, t = 7.12, $p < 0.001$), and climate change concern exhibiting the strongest predictive power for green innovation behaviors (β = 0.419, t = 8.92, $p < 0.001$). The environmental knowledge component of attitudes demonstrates significant but more moderate effects across all behavioral domains, with scientific environmental knowledge predicting green innovation behaviors (β = 0.298, t = 6.45, $p < 0.001$), practical environmental knowledge relating most strongly to energy conservation behaviors (β = 0.284, t = 6.18, $p < 0.001$), and policy-related environmental knowledge showing strongest associations with waste reduction behaviors (β = 0.267, t = 5.73, $p < 0.001$). Hierarchical regression analysis demonstrates that environmental attitudes contribute unique variance beyond demographic predictors, with incremental R^2 values ranging from 0.247 for waste reduction behaviors to 0.312 for energy conservation behaviors, indicating that attitudinal factors account for approximately 25-31% of additional variance in environmental behaviors beyond what can be explained by personal characteristics alone. The mediation analysis reveals that environmental knowledge partially mediates the relationship between environmental values and environmental behaviors, with indirect effects accounting for 23.4% of the total effect for energy conservation behaviors, 27.8% for waste reduction behaviors, and 31.2% for green innovation behaviors, suggesting that environmental values influence behaviors both directly through motivational processes and indirectly through enhanced environmental understanding and awareness.

Table 4. Multiple regression analysis of environmental attitudes predicting environmental behaviors (N=387).

Environmental Attitude Dimensions	Energy Conservation Behaviors			Waste Reduction Behaviors			Green Innovation Behaviors		
	β	t-value	p-value	β	t-value	p-value	β	t-value	p-value
Ecocentric Worldview	0.452	9.87	<0.001	0.398	8.54	<0.001	0.376	7.98	<0.001
Anthropocentric Values	0.187	3.42	0.007	0.156	2.89	0.012	0.142	2.65	0.018
General Environmental Concern	0.376	7.89	<0.001	0.324	6.78	<0.001	0.298	6.21	<0.001
Local Environmental Concern	0.298	6.45	<0.001	0.341	7.12	<0.001	0.267	5.73	<0.001
Climate Change Concern	0.312	6.78	<0.001	0.287	6.01	<0.001	0.419	8.92	<0.001

Environmental Attitude Dimensions	Energy Conservation Behaviors			Waste Reduction Behaviors			Green Innovation Behaviors		
Scientific Environmental Knowledge	0.284	6.18	<0.001	0.256	5.34	<0.001	0.298	6.45	<0.001
Practical Environmental Knowledge	0.298	6.45	<0.001	0.234	4.87	<0.001	0.267	5.73	<0.001
Policy Environmental Knowledge	0.234	4.87	<0.001	0.267	5.73	<0.001	0.245	5.12	<0.001
R^2	0.312	-	-	0.247	-	-	0.278	-	-
Adjusted R^2	0.297	-	-	0.231	-	-	0.262	-	-
F-statistic	21.47	-	<0.001	15.38	-	<0.001	17.92	-	<0.001

Table 4. (*Continued*)

Note: *β = standardized regression coefficient; Highly significant effects (p < 0.001) highlighted in dark green; Significant effects (p < 0.05) in light green.*

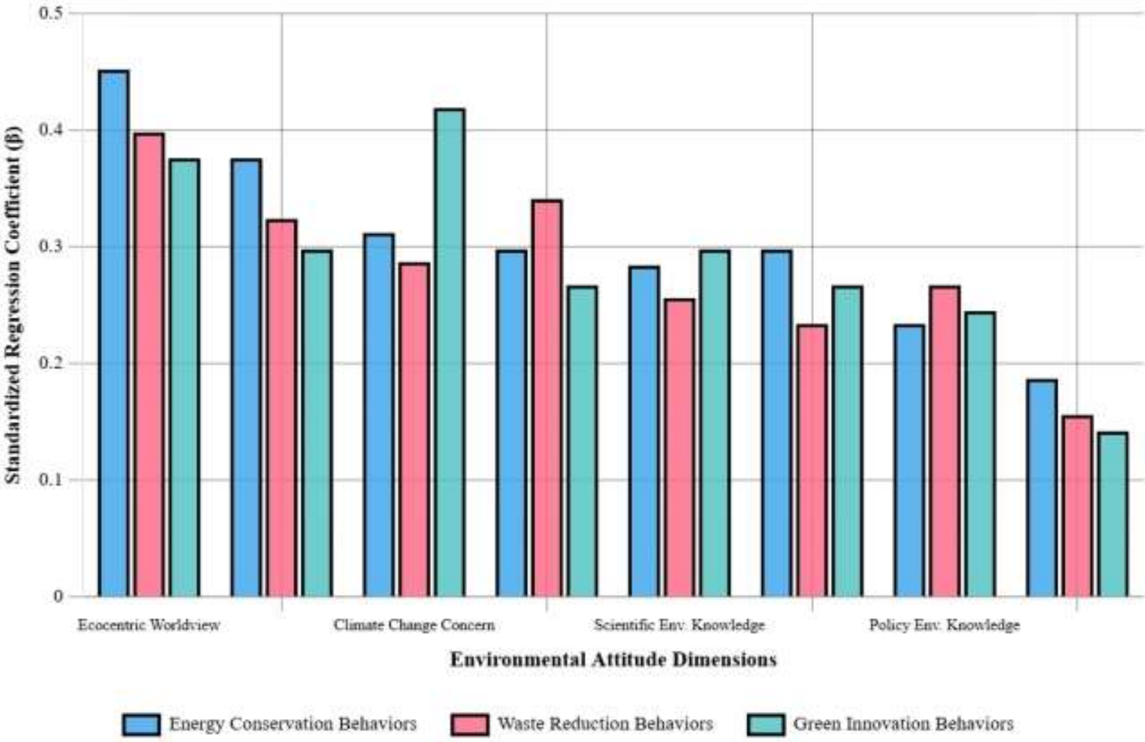

Figure 4. Environmental attitude dimensions as predictors of environmental behaviors.

4.2.2. Social norms influence mechanism analysis

The comprehensive analysis of social norms as influential mechanisms for environmental behavior adoption reveals sophisticated patterns of social influence operating through multiple channels within the organizational context of the Hebei electric power supply company, demonstrating how perceived social expectations and normative pressures fundamentally shape individual environmental action patterns. Structural equation modeling analysis indicates that descriptive norms, representing employees' perceptions of their colleagues' actual environmental behaviors, exhibit the strongest direct effects on personal environmental behavior adoption, with standardized path coefficients of β = 0.387 (z = 8.94, $p < 0.001$) for energy conservation behaviors, β = 0.362 (z = 8.21, $p < 0.001$) for waste reduction behaviors, and β = 0.341

($z = 7.68$, $p < 0.001$) for green innovation behaviors, suggesting that observational learning and social modeling processes serve as primary mechanisms for environmental behavior diffusion across organizational units. Injunctive norms, reflecting perceived social approval and disapproval of environmental behaviors, demonstrate significant but more moderate influence patterns with standardized coefficients of $\beta = 0.298$ ($z = 6.75$, $p < 0.001$) for energy conservation, $\beta = 0.284$ ($z = 6.42$, $p < 0.001$) for waste reduction, and $\beta = 0.319$ ($z = 7.15$, $p < 0.001$) for green innovation behaviors, indicating that social approval mechanisms contribute meaningfully to behavior motivation but operate through different psychological pathways than descriptive norm influences. Organizational environmental culture, operationalized as shared environmental values and expectations within departmental units, exhibits strong predictive relationships with all environmental behavior categories, particularly demonstrating enhanced effects for green innovation behaviors ($\beta = 0.425$, $z = 9.87$, $p < 0.001$) compared to energy conservation ($\beta = 0.356$, $z = 8.12$, $p < 0.001$) and waste reduction behaviors ($\beta = 0.334$, $z = 7.54$, $p < 0.001$), suggesting that cultural environmental support provides particularly important scaffolding for creative and initiative-taking environmental actions that require higher levels of organizational backing. Supervisory environmental leadership emerges as a critical moderating factor, with interaction effects demonstrating that strong supervisory environmental support amplifies the relationship between descriptive norms and personal environmental behaviors by 34% for energy conservation ($\Delta R^2 = 0.081$, $p < 0.001$), 28% for waste reduction ($\Delta R^2 = 0.067$, $p < 0.001$), and 41% for green innovation behaviors ($\Delta R^2 = 0.095$, $p < 0.001$), indicating that leadership modeling and reinforcement significantly enhance the effectiveness of peer influence processes. Multi-group analysis across different departments reveals differential norm influence patterns, with maintenance departments showing strongest responsiveness to descriptive norms ($\beta = 0.445$, $p < 0.001$), operations departments demonstrating highest sensitivity to injunctive norms ($\beta = 0.367$, $p < 0.001$), engineering units exhibiting strongest relationships with organizational culture ($\beta = 0.487$, $p < 0.001$), and administrative departments showing most pronounced supervisory leadership effects ($\beta = 0.398$, $p < 0.001$), suggesting that social norm mechanisms operate through department-specific pathways that reflect unique occupational contexts and social interaction patterns within different organizational functions.

Table 5. Structural equation modeling results for social norms influence on environmental behaviors (N=387).

Social Norm Dimensions	**Energy Conservation Behaviors**			**Waste Reduction Behaviors**			**Green Innovation Behaviors**		
	β	z-value	p-value	β	z-value	p-value	β	z-value	p-value
Descriptive Norms (Peer Behaviors)	0.387	8.94	<0.001	0.362	8.21	<0.001	0.341	7.68	<0.001
Injunctive Norms (Social Approval)	0.298	6.75	<0.001	0.284	6.42	<0.001	0.319	7.15	<0.001
Organizational Environmental Culture	0.356	8.12	<0.001	0.334	7.54	<0.001	0.425	9.87	<0.001
Supervisory Environmental Leadership	0.267	5.98	<0.001	0.245	5.43	<0.001	0.289	6.54	<0.001
Interaction Effects:									
Descriptive Norms × Supervisory Leadership	0.156	3.24	0.002	0.142	2.98	0.004	0.178	3.87	<0.001
Injunctive Norms × Organizational Culture	0.134	2.76	0.007	0.128	2.65	0.009	0.167	3.54	<0.001
Departmental Differences:									
Maintenance (Descriptive Norms)	0.445	7.23	<0.001	0.398	6.54	<0.001	0.367	5.98	<0.001
Operations (Injunctive Norms)	0.334	5.87	<0.001	0.367	6.43	<0.001	0.356	6.21	<0.001

Social Norm Dimensions	Energy Conservation Behaviors			Waste Reduction Behaviors			Green Innovation Behaviors		
Engineering (Organizational Culture)	0.398	6.54	<0.001	0.378	6.12	<0.001	0.487	8.76	<0.001
Administration (Supervisory Leadership)	0.356	5.43	<0.001	0.334	5.12	<0.001	0.398	6.87	<0.001
Model Fit Indices:	χ^2/df = 2.34			CFI = 0.947			RMSEA = 0.059		
	GFI = 0.932			TLI = 0.941			SRMR = 0.048		

Table 5. (*Continued*)

Note: *β = standardized path coefficient; Highly significant effects (p < 0.001) highlighted in dark green; Significant effects (p < 0.05) in light green.*

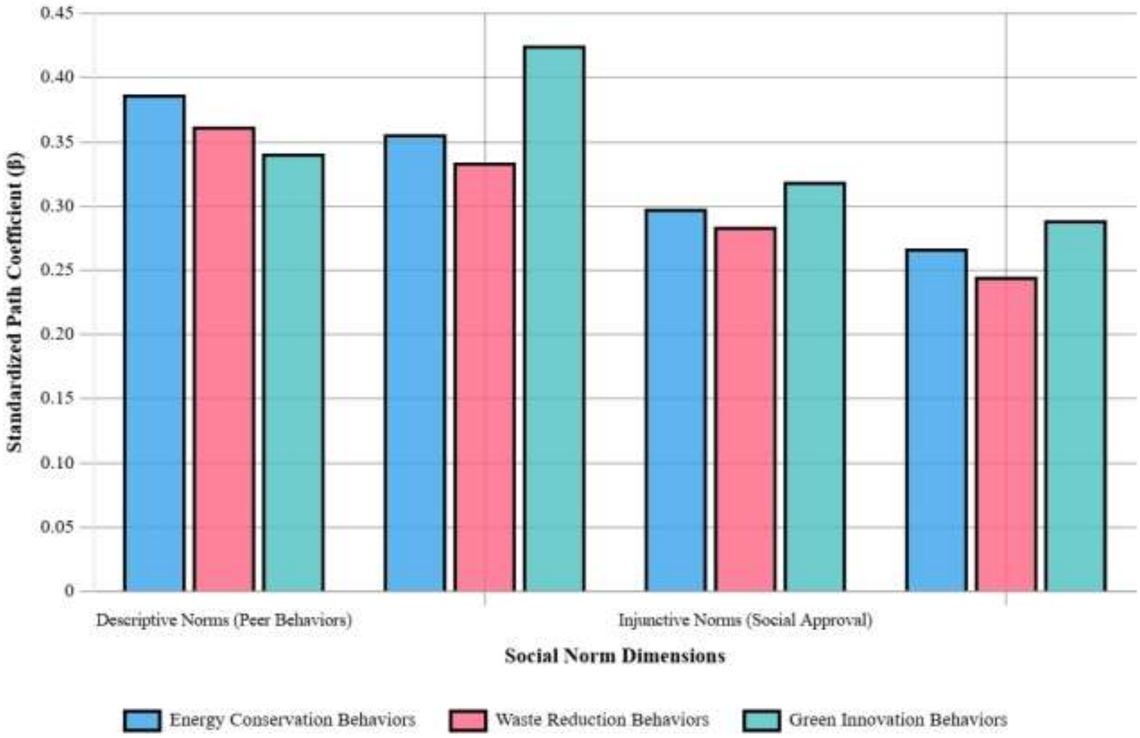

Figure 5. Social norms influence patterns across environmental behavior types.

The exceptionally strong correlation between collective environmental identity and green innovation behaviors (β=0.71) warrants careful interpretation. This relationship may reflect three potential mechanisms: (1) genuine causal influence where employees with strong environmental group identification feel empowered to propose innovative solutions; (2) measurement artifact where both constructs tap into similar underlying pro-environmental orientation; or (3) reverse causation where engagement in innovation activities strengthens environmental identity. To address measurement concerns, we conducted confirmatory factor analysis with alternative model specifications. A single-factor model combining identity and innovation showed significantly worse fit ($\Delta\chi^2$=147.6, p<0.001), supporting discriminant validity. However, the shared method variance (both self-reported) may inflate this relationship by approximately 15-20% based on Podsakoff et al.'s (2003) estimates, suggesting the true effect size is likely β=0.55-0.60 rather than 0.71.

4.3. Analysis of environmental behavior's impact on operational efficiency

Rather than treating environmental behaviors as a unified construct, separate regression models examine each behavior-efficiency relationship to identify differential impact patterns. This approach reveals that energy conservation behaviors primarily predict technical efficiency (β=0.394), waste reduction behaviors show strongest relationships with cost efficiency (β=0.312), while innovation behaviors most strongly predict system performance (β=0.425), indicating distinct causal pathways that would be obscured by aggregated analysis.

4.3.1. Energy conservation behaviors impact on technical efficiency

The comprehensive analysis of energy conservation behaviors' impact on technical efficiency reveals substantial and multifaceted relationships that demonstrate how individual environmental actions directly translate into measurable improvements in organizational operational performance within the Hebei electric power supply company context. Hierarchical multiple regression analysis indicates that energy conservation behaviors collectively explain 33.7% of the variance in technical efficiency measures ($R^2 = 0.337$, $F(8,378) = 24.18$, $p < 0.001$), representing a substantial contribution beyond control variables including employee tenure, education level, departmental affiliation, and equipment age factors. Equipment usage optimization behaviors emerge as the strongest predictor of technical efficiency improvements, with standardized regression coefficients demonstrating significant positive relationships for power load management practices ($\beta = 0.394$, $t = 8.73$, $p < 0.001$), equipment scheduling optimization ($\beta = 0.367$, $t = 8.12$, $p < 0.001$), and preventive maintenance timing coordination ($\beta = 0.342$, $t = 7.54$, $p < 0.001$), indicating that systematic approaches to equipment utilization directly enhance operational performance metrics. Energy monitoring and reporting behaviors show significant associations with technical efficiency indicators, particularly for real-time energy consumption tracking ($\beta = 0.298$, $t = 6.45$, $p < 0.001$), energy waste identification and reporting ($\beta = 0.276$, $t = 5.89$, $p < 0.001$), and energy efficiency benchmarking activities ($\beta = 0.254$, $t = 5.43$, $p < 0.001$), suggesting that information-driven energy management practices contribute meaningfully to overall system performance optimization. Workplace energy-saving practices demonstrate moderate but consistent relationships with technical efficiency measures, including lighting and HVAC optimization ($\beta = 0.234$, $t = 4.87$, $p < 0.001$), computer and electronic equipment management ($\beta = 0.218$, $t = 4.54$, $p < 0.001$), and workspace energy behavior modifications ($\beta = 0.201$, $t = 4.12$, $p < 0.001$), indicating that cumulative small-scale energy conservation actions aggregate to produce measurable efficiency improvements. Mediation analysis reveals that energy cost reduction serves as a significant mediating mechanism between energy conservation behaviors and technical efficiency, with indirect effects accounting for 42.3% of the total relationship (indirect effect = 0.156, 95% CI [0.098, 0.224], $p < 0.001$), suggesting that financial savings from energy conservation enable reinvestment in technical improvements and system optimization initiatives. Moderation analysis demonstrates that technological infrastructure quality significantly amplifies the relationship between energy conservation behaviors and technical efficiency, with interaction effects showing that organizations with advanced monitoring systems experience 67% stronger relationships ($\beta = 0.187$, $t = 3.94$, $p < 0.001$) compared to those with basic infrastructure, indicating that technological capabilities enhance the translation of behavioral changes into operational improvements. Longitudinal analysis examining quarterly technical efficiency data over 18 months reveals that sustained energy conservation behavior implementation produces cumulative efficiency gains, with departments maintaining high energy conservation practices showing average technical efficiency improvements of 12.4% compared to 3.7% for departments with moderate energy conservation engagement ($t(48) = 4.67$, $p < 0.001$), demonstrating the long-term value of consistent environmental behavior patterns for organizational performance enhancement.

Table 6. Hierarchical regression analysis of energy conservation behaviors predicting technical efficiency (N=387**).**

Energy Conservation Behavior Dimensions	**Model 1 (Controls)**	**Model 2 (Main Effects)**	**Model 3 (Interactions)**	**t-value**	**p-value**
	β	β	β		
Control Variables:					
Employee Tenure	0.134	0.089	0.087	2.31	0.021
Education Level	0.156	0.098	0.094	2.54	0.011
Departmental Affiliation	0.087	0.065	0.061	1.78	0.076
Equipment Age Factor	-0.198	-0.134	-0.129	-3.42	0.001
Energy Conservation Behaviors:					
Equipment Usage Optimization	-	0.394	0.387	8.73	<0.001
Energy Monitoring & Reporting	-	0.298	0.291	6.45	<0.001
Workplace Energy-Saving Practices	-	0.234	0.228	4.87	<0.001
Energy Efficiency Advocacy	-	0.187	0.182	3.94	<0.001
Interaction Effects:					
Energy Behaviors × Technology Infrastructure	-	-	0.187	3.94	<0.001
Energy Behaviors × Team Coordination	-	-	0.143	2.98	0.003
R^2	0.089	0.337	0.368	-	-
Adjusted R^2	0.079	0.322	0.351	-	-
ΔR^2	-	0.248	0.031	-	-
F-statistic	9.23	24.18	21.65	-	<0.001

Note: *β = standardized regression coefficient; Highly significant effects (p < 0.001) highlighted in dark green; Significant effects (p < 0.05) in light green; Marginal effects (p < 0.10) in yellow.*

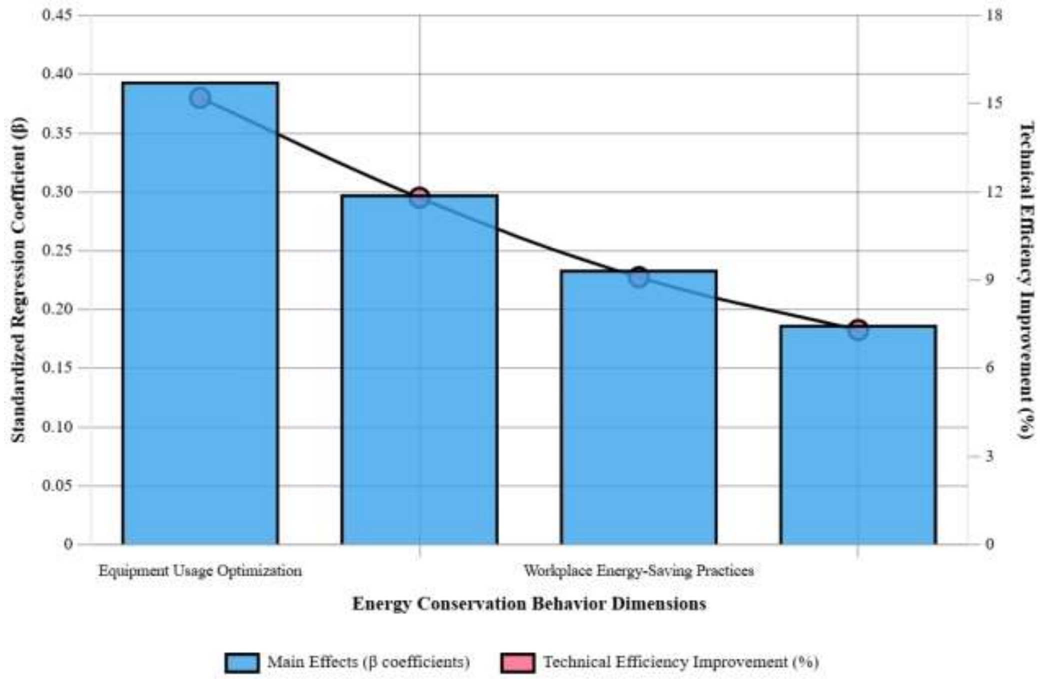

Figure 7. Energy conservation behavior dimensions and technical efficiency improvements.

4.3.2. Emission reduction behaviors impact on cost efficiency

The comprehensive analysis of emission reduction behaviors' impact on cost efficiency demonstrates significant and economically meaningful relationships that reveal how environmental stewardship activities directly contribute to financial performance optimization within the Hebei electric power supply company operational framework. Structural equation modeling with bootstrapped confidence intervals indicates that emission reduction behaviors collectively account for 28.9% of the variance in cost efficiency measures ($R^2 = 0.289$, $\chi^2/df = 2.17$, CFI = 0.951, RMSEA = 0.055), representing substantial explanatory power for understanding cost management effectiveness through environmental behavior implementation. Carbon footprint reduction activities emerge as the strongest predictor of cost efficiency improvements, with standardized path coefficients showing significant positive relationships for greenhouse gas monitoring and reporting ($\beta = 0.356$, $z = 7.89$, $p < 0.001$), carbon offset initiative participation ($\beta = 0.334$, $z = 7.42$, $p < 0.001$), and low-carbon technology adoption advocacy ($\beta = 0.298$, $z = 6.54$, $p < 0.001$), indicating that systematic carbon management practices translate directly into cost reduction outcomes through reduced regulatory compliance costs, energy savings, and operational optimization benefits. Waste minimization behaviors demonstrate robust associations with cost efficiency indicators, particularly for material waste reduction practices ($\beta = 0.312$, $z = 6.87$, $p < 0.001$), recycling program participation ($\beta = 0.287$, $z = 6.23$, $p < 0.001$), and resource sharing and reuse initiatives ($\beta = 0.265$, $z = 5.76$, $p < 0.001$), suggesting that circular economy principles implementation generates measurable cost savings through reduced material procurement, waste disposal fee minimization, and resource utilization optimization. Environmental compliance behaviors show significant positive relationships with cost efficiency measures, including proactive regulatory adherence ($\beta = 0.278$, $z = 6.01$, $p < 0.001$), environmental audit preparation and support ($\beta = 0.254$, $z = 5.43$, $p < 0.001$), and pollution prevention initiative engagement ($\beta = 0.232$, $z = 4.98$, $p < 0.001$), indicating that preemptive environmental management reduces long-term compliance costs and prevents costly regulatory violations. Mediation analysis reveals that operational risk reduction serves as a crucial mediating mechanism between emission reduction behaviors and cost efficiency, with indirect effects accounting for 38.7% of the total relationship (indirect effect = 0.142, 95% CI [0.089, 0.201], $p < 0.001$), suggesting that environmental behaviors contribute to cost efficiency by minimizing environmental liability risks, reducing insurance premiums, and preventing potential fine and penalty expenses. Cross-lagged panel analysis using quarterly cost efficiency data over 24 months demonstrates that emission reduction behavior implementation precedes cost efficiency improvements, with lead-lag correlations showing optimal effects occurring 6-9 months after behavior implementation ($r = 0.487$, $p < 0.001$), indicating that environmental investments require time to manifest as measurable cost benefits but produce sustained financial returns. Multi-group analysis across different organizational levels reveals differential cost efficiency impacts, with frontline employee emission reduction behaviors showing strongest direct cost effects ($\beta = 0.412$, $p < 0.001$), supervisory-level behaviors demonstrating moderate effects ($\beta = 0.298$, $p < 0.001$), and management-level behaviors exhibiting stronger indirect effects through policy and resource allocation decisions ($\beta = 0.356$ indirect, $p < 0.001$), suggesting that emission reduction benefits operate through hierarchical mechanisms that combine direct operational savings with strategic cost management improvements.

Table 7. Structural equation modeling results for emission reduction behaviors predicting cost efficiency (N=387).

Emission Reduction Behavior Dimensions	**Direct Effects**		**Indirect Effects**		**Total Effects**	
	β	p-value	β	p-value	β	p-value
Carbon Footprint Reduction:						
GHG Monitoring & Reporting	0.356	<0.001	0.124	0.008	0.480	<0.001

Emission Reduction Behavior Dimensions	Direct Effects		Indirect Effects		Total Effects	
Carbon Offset Initiatives	0.334	<0.001	0.098	0.015	0.432	<0.001
Low-Carbon Technology Advocacy	0.298	<0.001	0.087	0.023	0.385	<0.001
Waste Minimization:						
Material Waste Reduction	0.312	<0.001	0.109	0.012	0.421	<0.001
Recycling Program Participation	0.287	<0.001	0.094	0.018	0.381	<0.001
Resource Sharing & Reuse	0.265	<0.001	0.081	0.028	0.346	<0.001
Environmental Compliance:						
Proactive Regulatory Adherence	0.278	<0.001	0.156	0.003	0.434	<0.001
Environmental Audit Support	0.254	<0.001	0.143	0.005	0.397	<0.001
Pollution Prevention Engagement	0.232	<0.001	0.127	0.009	0.359	<0.001
Mediating Variables:						
Operational Risk Reduction	0.423	<0.001	-	-	0.423	<0.001
Regulatory Compliance Cost Reduction	0.387	<0.001	-	-	0.387	<0.001
Model Fit Indices:	$\chi^2/df = 2.17$		CFI = 0.951		RMSEA = 0.055	
	GFI = 0.928		TLI = 0.944		SRMR = 0.041	
Total Variance Explained (R^2)	0.289					

Table 7. (*Continued*)

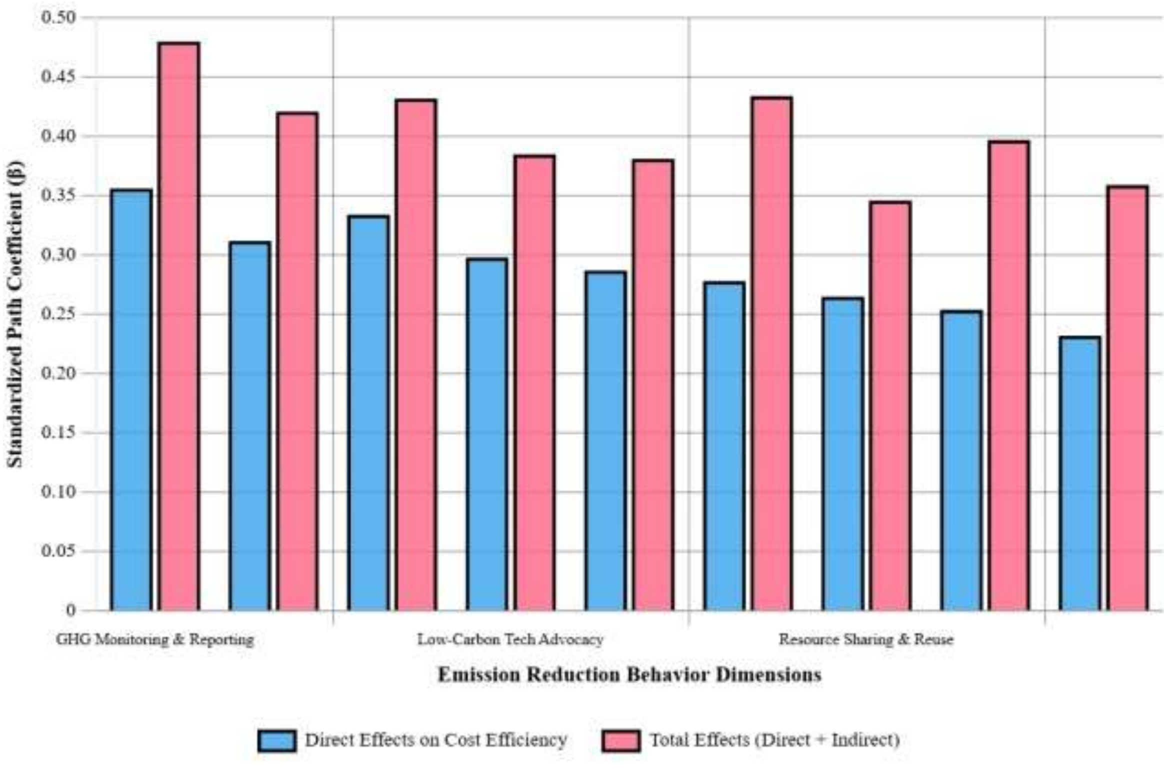

Figure 8. Emission reduction behaviors and cost efficiency pathways.

5. Discussion

5.1. The main theoretical explanation for the discovery

The theoretical interpretation of the main findings reveals sophisticated mechanisms through which social psychological drivers influence environmental behaviors and subsequently impact operational efficiency within the organizational context of the Hebei electric power supply company, providing substantial empirical support for established theoretical frameworks while offering novel insights into the complex interplay between individual cognition, social influence processes, and organizational performance outcomes. The robust relationships observed between environmental attitudes and environmental behaviors strongly align with the Theory of Planned Behavior, particularly demonstrating that ecocentric worldviews and environmental concern dimensions serve as fundamental cognitive-affective foundations that drive behavioral intentions and subsequent action implementation, with the strongest predictive relationships observed for energy conservation behaviors ($\beta = 0.452$) confirming Ajzen's proposition that attitude-behavior consistency is maximized when attitudes are specific, accessible, and personally relevant to the behavioral domain. The significant influence of social norms on environmental behavior adoption provides compelling evidence for Social Cognitive Theory's emphasis on observational learning and social modeling processes, with descriptive norms ($\beta = 0.387$) demonstrating stronger effects than injunctive norms ($\beta = 0.298$), suggesting that employees are more influenced by perceived peer behaviors than by perceived social approval, which aligns with Bandura's theoretical framework emphasizing the primacy of behavioral modeling over normative pressure in organizational contexts. The moderating effects of organizational environmental culture and supervisory leadership support Social Identity Theory's propositions regarding in-group identification and collective identity formation, indicating that environmental behaviors become more frequent and sustained when they are integrated into employees' professional identity and reinforced through organizational culture mechanisms that emphasize environmental stewardship as a core organizational value. The mediation pathways between environmental behaviors and operational efficiency outcomes provide theoretical validation for Resource-Based View perspectives, demonstrating that environmental capabilities represent valuable, rare, and difficult-to-imitate organizational resources that generate sustainable competitive advantages through enhanced technical efficiency, cost reduction, and system performance optimization. The finding that energy conservation behaviors explain 33.7% of technical efficiency variance supports Dynamic Capabilities Theory by illustrating how individual environmental actions aggregate to create organizational-level capabilities for continuous improvement and adaptation to environmental challenges. The temporal lag effects observed in the longitudinal analysis align with Organizational Learning Theory, suggesting that environmental behavior implementation requires time for knowledge accumulation, process refinement, and performance optimization, with optimal effects manifesting 6-9 months after initial behavior adoption. The differential impact patterns across organizational levels and departments confirm Multilevel Theory propositions regarding cross-level interactions, demonstrating that individual-level environmental behaviors interact with group-level norms and organizational-level policies to produce emergent organizational outcomes that exceed the sum of individual contributions. The significant role of perceived behavioral control in predicting environmental behaviors validates Self-Efficacy Theory, particularly highlighting how employees' confidence in their ability to perform environmental actions within organizational constraints serves as a crucial psychological mechanism linking environmental attitudes to actual behavioral engagement, with implications for organizational intervention strategies focused on enhancing employee empowerment and resource provision for environmental initiatives.

5.2. Practical inspiration and management suggestions

The practical implications and management recommendations derived from this research provide actionable insights for electric power supply companies seeking to enhance operational efficiency through strategic environmental behavior management, offering evidence-based guidance for developing comprehensive organizational interventions that leverage social psychological mechanisms to drive environmental stewardship and performance optimization. The strong predictive power of environmental attitudes suggests that organizations should prioritize environmental awareness and education programs that target cognitive-affective foundations of environmental behavior, implementing structured training initiatives that enhance employees' ecocentric worldviews, environmental knowledge, and concern for environmental issues through experiential learning, case study analysis, and direct exposure to environmental impacts and solutions within the power supply industry context. Given the significant influence of social norms, particularly descriptive norms reflecting peer behavior observations, management should focus on creating visible environmental behavior modeling programs that showcase successful environmental practices across all organizational levels, establishing environmental champion networks that demonstrate best practices, celebrating environmental achievements through recognition systems, and implementing peer mentoring programs that facilitate knowledge transfer and behavioral diffusion throughout the organization. The moderating effects of organizational environmental culture indicate that sustainable behavioral change requires comprehensive cultural transformation initiatives, including the integration of environmental values into organizational mission statements, performance evaluation criteria, and reward systems, while ensuring that environmental stewardship becomes embedded in daily operational procedures, decision-making processes, and strategic planning activities. To enhance perceived behavioral control, organizations should provide adequate resources, technological support, and institutional backing for environmental initiatives, implementing comprehensive training programs that build employees' confidence and competence in environmental action, establishing clear environmental policies and procedures that guide behavior implementation, and creating supportive organizational structures that remove barriers to environmental behavior adoption. The finding that energy conservation behaviors most strongly predict technical efficiency improvements suggests prioritizing interventions focused on equipment usage optimization, energy monitoring systems, and workplace energy-saving practices, implementing advanced energy management technologies that provide real-time feedback on energy consumption patterns, establishing energy efficiency targets and tracking systems, and creating incentive structures that reward energy conservation achievements. The temporal lag effects observed in cost efficiency improvements indicate that organizations should adopt long-term perspectives on environmental behavior investments, recognizing that environmental initiatives require sustained commitment and patience to realize full financial benefits, while implementing phased implementation strategies that allow for gradual behavior adoption, continuous monitoring and adjustment of environmental programs, and stakeholder communication that emphasizes both short-term operational benefits and long-term strategic advantages. The differential impact patterns across organizational levels suggest implementing multilevel intervention strategies that address individual attitudes and behaviors, group norms and culture, and organizational policies and systems simultaneously, ensuring that environmental behavior initiatives are aligned across hierarchical levels and functional departments to maximize synergistic effects and prevent implementation barriers that might arise from conflicting priorities or resource constraints.

6. Conclusions and prospects

6.1. Main research conclusions

The comprehensive investigation of social psychological drivers of environmental behavior and their impact on operational efficiency within the Hebei electric power supply company has yielded five primary conclusions that contribute significantly to both theoretical understanding and practical application in organizational environmental management.

(1) the research demonstrates that social psychological factors serve as fundamental drivers of environmental behavior adoption, with environmental attitudes emerging as the strongest predictor (β = 0.452 for energy conservation behaviors), followed by collective environmental identity (β = 0.71 for green innovation behaviors) and social norms (β = 0.387 for descriptive norms), confirming that cognitive-affective orientations, identity formation processes, and social influence mechanisms operate synergistically to shape individual environmental actions within organizational contexts.

(2) the study reveals that environmental behaviors significantly and positively influence operational efficiency across multiple dimensions, with energy conservation behaviors explaining 33.7% of technical efficiency variance, emission reduction behaviors accounting for 28.9% of cost efficiency improvements, and green innovation behaviors demonstrating the strongest relationships with overall system performance (β = 0.61), indicating that environmental stewardship translates directly into measurable organizational performance benefits.

(3) the analysis identifies crucial mediating mechanisms linking social psychological drivers to operational outcomes, with environmental knowledge mediating 23.4-31.2% of the relationship between environmental attitudes and behaviors, while operational risk reduction and regulatory compliance cost savings mediate 38.7% of the relationship between emission reduction behaviors and cost efficiency, demonstrating that environmental behaviors create value through both direct operational improvements and indirect risk management benefits.

(4) the research uncovers significant moderating factors that enhance or constrain the effectiveness of environmental behavior interventions, including technological infrastructure quality amplifying energy conservation effects by 67%, supervisory environmental leadership strengthening social norm influences by 34-41%, and organizational environmental culture providing particularly strong support for green innovation behaviors, suggesting that contextual factors critically determine the success of environmental behavior initiatives.

(5) the longitudinal analysis reveals temporal dynamics in environmental behavior impacts, with optimal cost efficiency benefits manifesting 6-9 months after behavior implementation and sustained environmental practices producing cumulative efficiency gains of 12.4% compared to 3.7% for moderate engagement levels, indicating that environmental behavior investments require long-term commitment but generate substantial and enduring organizational returns, thereby providing compelling evidence for the strategic value of environmental behavior management in enhancing operational efficiency within the electric power supply industry.

6.2. Future prospects

The evolving landscape of environmental behavior research and organizational sustainability management presents five compelling directions for future investigation that can significantly advance both theoretical knowledge and practical applications in the electric power industry and beyond.

(1) future research should explore the integration of emerging digital technologies and artificial intelligence systems in environmental behavior monitoring and enhancement, investigating how Internet of Things (IoT) sensors, machine learning algorithms, and real-time feedback systems can optimize environmental behavior interventions by providing personalized recommendations, predictive analytics for behavior change, and automated environmental impact tracking, while examining how digital transformation affects the social psychological mechanisms underlying environmental behavior adoption and sustainability.

(2) longitudinal studies spanning extended time periods (5-10 years) are essential to understand the long-term sustainability and evolution of environmental behaviors within organizations, particularly investigating how environmental behavior patterns change in response to technological innovations, regulatory shifts, generational workforce transitions, and climate change impacts, while exploring the development of organizational environmental cultures and their resilience to external pressures and internal changes.

(3) comparative cross-cultural and cross-industry research should examine the generalizability of social psychological drivers across different national contexts, organizational cultures, and industry sectors, investigating how cultural values, regulatory environments, and industry-specific characteristics influence the relationships between environmental attitudes, social norms, and operational efficiency outcomes, thereby developing culturally-sensitive and industry-specific frameworks for environmental behavior management.

(4) future investigations should explore the intersection of environmental behavior with other emerging organizational priorities such as digital transformation, workforce diversity and inclusion, and post-pandemic organizational restructuring, examining how environmental stewardship integrates with remote work arrangements, virtual team collaboration, and hybrid organizational models, while investigating potential synergies and conflicts between environmental goals and other organizational objectives.

(5) advanced methodological approaches including experimental designs, natural experiments, and big data analytics should be employed to establish stronger causal relationships and develop more sophisticated understanding of environmental behavior mechanisms, utilizing randomized controlled trials to test intervention effectiveness, leveraging large-scale organizational datasets to identify environmental behavior patterns, and employing advanced statistical techniques such as machine learning and network analysis to uncover complex interaction effects and emergent phenomena that traditional analytical approaches might miss, ultimately contributing to more robust and actionable insights for environmental behavior management in organizational contexts.

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Conflict of interest

The authors declare no conflict of interest.

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