

RESEARCH ARTICLE

Under the background of zero-carbon transformation, the collaborative mechanism between the low-carbon atmosphere of enterprises and employees' environmental identity recognition

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ABSTRACT

To reveal the interactive patterns between corporate low-carbon climate and employee environmental identity in the context of zero-carbon transformation, this study adopts a mixed research method combining case studies and questionnaire surveys. Taking zero-carbon transformation enterprises in the new energy, high-end manufacturing, and chemical industries as case subjects, 122 valid questionnaire data were collected simultaneously. The collaborative mechanism between the two was verified through qualitative coding and quantitative regression analysis. The results indicate that the cognitive, institutional, and behavioral dimensions of corporate low-carbon climate differentially positively drive the identity cognition, identity emotion, and identity behavioral intention dimensions of employee environmental identity. Among them, cognitive climate has the strongest driving effect on identity cognition, institutional climate on identity emotion, and behavioral climate on identity behavioral intention. Employee environmental identity has a reverse feedback effect on corporate low-carbon climate, with identity cognition having the strongest feedback effect on cognitive climate, identity emotion on institutional climate, and identity behavioral intention on behavioral climate. The two form a collaborative closed loop through positive driving and reverse feedback, and employee education level, job type, and enterprise industry attributes and scale significantly modulate the synergistic effect. The research conclusion provides theoretical basis and practical reference for enterprises to strengthen employee environmental identity and enhance the efficiency of zero-carbon transformation through the construction of a low-carbon climate.

Keywords: zero-carbon transition; corporate low-carbon culture; employee environmental identity; collaborative mechanism

1. Introduction

The accelerated process of global climate governance has driven enterprises into a critical stage of zero-carbon transition. Low carbon has gradually evolved from a policy requirement to a core development strategy for enterprises, and employees' active participation is the key support for the implementation of the transition. The degree of their environmental identity directly determines the sustainability and depth of low-carbon behaviors. As an important organizational carrier for promoting low-carbon transition, existing

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research on corporate low-carbon climate mainly focuses on its constituent dimensions and one-way impact effects. In terms of constituent dimension research, some scholars simplify it into institutional restrictive elements, such as the formulation of low-carbon policies and reward-punishment rules^[1,8], emphasizing the guidance of employees' compliant behaviors through rigid norms. Other studies focus on cognitive communication functions, arguing that the promotion of corporate low-carbon concepts and knowledge training are the core of climate building^[3], which indirectly affect behavioral decisions by enhancing employees' low-carbon cognition. However, most existing studies explore the role of a single dimension in isolation, lacking an integrated analysis of the three dimensions of cognition, institution, and behavior, and failing to reveal the differentiated functions and synergistic effects of each dimension. In terms of impact effect research, most literatures focus on the one-way shaping of employees' low-carbon behaviors by corporate low-carbon climate, such as verifying the restrictive effect of low-carbon systems on employees' energy-saving behaviors and garbage classification behaviors^[6], or exploring the promoting effect of cognitive climate on employees' willingness to participate in low-carbon activities^[7]. Nevertheless, they all ignore the reverse effect of individual employees on the climate, treating employees as passive recipients rather than active constructors, which leads to limited understanding of the interactive relationship between the two.

As a core psychological variable driving low-carbon behaviors at the individual level, existing research on employees' environmental identity mainly focuses on its formation path and behavioral impacts. In terms of formation path, most studies start from individual psychological traits, such as exploring the shaping effect of internal factors like values, environmental awareness, and self-efficacy on identity^[9,10], while paying insufficient attention to external situational factors at the organizational level. A few studies involving organizational factors only take corporate low-carbon practices as a general background variable, failing to deeply analyze how the specific situational factor of corporate low-carbon climate affects the cognitive, emotional, and behavioral intention dimensions of identity through multi-dimensional interactions.

Based on the current status of the two research branches, it is evident that existing literatures have obvious fragmented limitations. On one hand, research on corporate low-carbon climate and employees' environmental identity mostly exists in isolation, lacking systematic exploration of their inherent connections. On the other hand, even a few studies involving their one-way connection fail to break through the single logic of "organization shaping individuals" and ignore the reverse mechanism of "individuals feeding back organizations", resulting in a superficial understanding of the relationship between the two. Against this background, it is necessary to explore the inherent connection between corporate low-carbon climate and employees' environmental identity, so as to solve the problem of fragmentation of existing research and disconnection from practical applications.

2. Research design and data sources

2.1. Selection and design of research methods

This study adopts a mixed research method combining case studies and questionnaire surveys. The reasons for choosing this method include: case studies can analyze the interactive process between the corporate low-carbon atmosphere and employees' environmental identity, identify the characteristics of collaborative mechanisms, and are suitable for mechanism exploration; questionnaire surveys quantitatively verify the collaborative relationships refined through case studies through large sample data, test the universality of the mechanisms, and compensate for the limitations of single case studies^[3].

2.2. Case study design

2.2.1. Case selection criteria and objects

The selection of cases follows the principle of theoretical sampling, with specific criteria and targets as follows: In terms of industry representativeness, industries with clear policy orientation towards zero-carbon transformation and urgent demand for low-carbon practices are selected, including new energy, high-end manufacturing, and chemical industries. These industries have high requirements for employees' environmental awareness in low-carbon practices, which facilitates the observation of collaborative mechanisms. In terms of adaptability during the transformation stage, enterprises in the deepening transformation period are selected, that is, those that have completed the construction of basic low-carbon facilities and entered the stage of institutional improvement and employee behavior penetration. At this time, the interaction between the low-carbon atmosphere in the enterprise and employees' environmental identity is more evident. In terms of data availability, enterprises that cooperate with interviews and can provide low-carbon practice materials such as annual ESG reports and internal institutional documents are selected. Finally, three case enterprises are determined, namely, a new energy technology company (Enterprise A), an automobile manufacturing enterprise (Enterprise B), and a green chemical enterprise (Enterprise C).

2.2.2. Case data collection method

The multi-source data triangulation method is adopted to ensure the comprehensiveness and credibility of the data. The specific collection methods are as follows: Semi-structured interviews are conducted with senior and middle-level managers in the enterprise, such as the head of the ESG department, the HR director, and department heads from production, administration, and grassroots employees. Each type of interviewee is interviewed for 3-5 people, with a cumulative interview duration of 15-20 hours per enterprise. The interviews focus on low-carbon atmosphere construction measures, employees' environmental identity recognition performance, and their interactive feelings. Field observations are conducted in the enterprise's production workshops and office areas, observing the layout of low-carbon facilities such as energy-saving lamps, garbage classification stations, and low-carbon promotional materials such as posters and bulletin boards. Daily low-carbon behaviors of employees, such as turning off lights when leaving and using environmentally friendly tableware, are recorded. Secondary data collection involves obtaining publicly available ESG reports, social responsibility reports, internal low-carbon management systems, employee manuals, training materials, and media reports on the enterprise's low-carbon practices, which supplement the interview and observation data^[4].

2.2.3. Case data coding and analysis methods

Using the three-level coding method of qualitative research and based on Glaser's grounded theory^[5], data analysis was conducted through Nvivo software. The specific steps are as follows: In the open coding stage, the interview transcripts, observation records, and secondary data were disassembled sentence by sentence to extract initial concepts, such as extracting low-carbon knowledge dissemination from the company's monthly organization of low-carbon knowledge training and extracting personal environmental responsibility perception from "I feel responsible for practicing low-carbon behavior"; in the axial coding stage, the initial concepts obtained from open coding were classified, categories were refined, and the relationships between categories were sorted out. For example, low-carbon knowledge dissemination, low-carbon institutional constraints, and low-carbon incentive measures were classified under the category of corporate low-carbon atmosphere, while personal environmental responsibility perception and environmental value recognition were classified under the category of employee environmental identity recognition; in the selective coding stage, the core category was determined as the collaborative mechanism between corporate

low-carbon atmosphere and employee environmental identity recognition. The axial coding categories were associated with the core category to construct a theoretical logic of "low-carbon atmosphere construction - employee identity recognition enhancement - collaborative effect output". The reliability of the analysis process was ensured through researcher triangulation, with two researchers independently coding and calculating the coding consistency coefficient, known as the Kappa value. When the Kappa value is greater than 0.8, the coding is confirmed to be valid.

2.3. Questionnaire survey design

2.3.1. Variable measurement dimensions and item design

The core variables of the questionnaire include corporate low-carbon climate, which serves as the independent variable, and employee environmental identity, which serves as the dependent variable^[6]. Control variables such as employee age, education level, and job position type are also included. All items adopt a Likert 5-point scale, with 1 representing "completely disagree" and 5 representing "completely agree". The specific dimensions and items are shown in **Table 1**:

Table 1. Questionnaire dimensions and items.

Variable type	Variable name	Measurement dimension
Independent variable	Corporate low-carbon culture	1. Cognitive atmosphere 2. Institutional atmosphere 3. Behavioral atmosphere
Dependent variable	Employee environmental identity	1. Identity cognition 2. Identity and emotion 3. Identity behavior intention
Control variable	Individual characteristics of employees	1. Age range is 20-30 years old, etc 2. Educational background ranging from high school and below to master's degree and above 3. The job type includes production, administrative, technical, and other positions

2.3.2. Scope of sample selection and sampling method

The sample encompasses domestic enterprises undergoing zero-carbon transformation, spanning four industries: new energy, manufacturing, chemical, and construction. It balances state-owned and private enterprises to ensure diversity in both industry and corporate nature. The sampling method employs stratified sampling: initially stratified by industry, then further stratified within each industry based on enterprise size, namely large and medium-sized enterprises. Finally, within each stratum, enterprises are randomly selected for questionnaire distribution. The sample size estimation follows the principle proposed by Hair et al. in 2010, which states that the sample size for structural equation modeling should be 5-10 times the number of items. This questionnaire has a total of 22 core items, requiring a minimum sample size of 110; considering a 15% invalid questionnaire return rate, it is planned to distribute 130 questionnaires.

2.3.3. Questionnaire distribution and collection process

The questionnaire distribution was conducted through a combination of online and offline methods, and was carried out in two stages: In the pre-research stage, 30 pre-research questionnaires were distributed to one non-sample enterprise, a medium-sized manufacturing enterprise. After collection, items with weak discriminability were deleted through item analysis, using the critical ratio method. Items with a CR value less than 3.0 were subjected to Cronbach's α coefficient reliability testing. An α value greater than 0.7 was considered satisfactory, and the questionnaire item wording was optimized. In the formal research stage, with

the assistance of the human resources department of the enterprise, questionnaires were distributed to employees of the sample enterprises. Online, links were sent through the Wenjuanxing platform, while offline, paper questionnaires were distributed centrally in the enterprise conference room. The research period was two weeks, during which employees who did not fill out the questionnaire were reminded via phone or WeChat to improve the response rate^[7]. After the questionnaire was collected, invalid questionnaires with filling times less than 60 seconds or with regular answers such as selecting all three options were eliminated, and valid questionnaires were retained for subsequent analysis.

2.3.4. Questionnaire data processing method

Data were processed using SPSS 26.0 and AMOS 24.0 software. The specific methods are as follows: Cronbach's α coefficient was used to test the reliability of the scale for reliability and validity assessment. Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were used to test the construct validity, where CFA needs to meet the fit indices of $\chi^2/df < 3$, GFI > 0.9 , and RMSEA < 0.08 . Common Method Bias was tested using Harman's Single Factor Test. Unrotated EFA was conducted on all items, and if the variance explained by the first factor is less than 40%, it indicates that common method bias is not significant^[8]. Descriptive statistics were used to calculate the mean and standard deviation of each variable to grasp the overall distribution of sample data. Correlation analysis was conducted using Pearson correlation analysis to examine the correlation between each dimension of corporate low-carbon climate and each dimension of employee environmental identity, and to determine the direction and strength of the association between variables. Regression analysis was used to construct a multiple linear regression model, with each dimension of corporate low-carbon climate as the independent variable and each dimension of employee environmental identity as the dependent variable. After controlling for individual characteristics of employees, the effect of the independent variables on the dependent variables was tested to verify the significance of the collaborative relationship.

2.4. Data quality control measures

To ensure the reliability and validity of case and questionnaire data, this study implemented quality control measures throughout the entire data collection and analysis process. In terms of case study data control, multi-source data triangulation was adopted, with interviews, observations, and secondary data corroborating each other to avoid bias from a single data source. Researchers were trained before interviews to standardize interviewing techniques and recording standards, reducing the subjective influence of researchers. In terms of questionnaire survey data control, the item design referenced mature scales and was optimized based on pre-research, ensuring clear and unambiguous expressions. Employees were informed before distributing the questionnaire that it was anonymous and would only be used for academic research, reducing social desirability bias. After collection, invalid questionnaires were screened, and samples with logical contradictions or perfunctory responses were eliminated. In terms of analysis process control, case coding was independently conducted by two researchers and their consistency was verified. Before questionnaire data analysis, reliability, validity, and common method bias tests were conducted to ensure the scientificity of the analysis results. All data processing steps were documented for subsequent verification and replication^[9,10].

2.5. Research Model

Based on the core variables and collaborative logic mentioned earlier, a research model is constructed to reflect the bidirectional influence between corporate low-carbon atmosphere and employee environmental identity recognition. The expression is as follows:

$$I_t \times A_{t+1} = \beta_1 \times A_t \times C + \beta_2 \times I_{t-1} \times A_t + \varepsilon$$

Where A_t represents the comprehensive value of corporate low-carbon atmosphere in period t , calculated by weighting cognitive atmosphere, institutional atmosphere, and behavioral atmosphere according to their respective weights; I_t represents the comprehensive value of employee environmental identity in period t , calculated by weighting identity cognition, identity emotion, and identity behavioral intention according to their respective weights; A_{t+1} represents the comprehensive value of corporate low-carbon atmosphere in period $t+1$; C represents the adjustment term of employee individual characteristics, calculated by weighting adjustment coefficients of age, education, and job type; β_1 represents the positive impact coefficient of corporate low-carbon atmosphere on employee environmental identity, and β_2 represents the negative impact coefficient of employee environmental identity on corporate low-carbon atmosphere; ε represents the random error term, with values satisfying a normal distribution.

3. Result analysis

3.1. Analysis of the impact of corporate low-carbon atmosphere on employees' environmental identity recognition

This section is based on the analysis of valid questionnaire data collected from a formal survey, with a total of 122 valid questionnaires returned, representing an effective response rate of 93.8%. The sample covers four industries: new energy, manufacturing, chemical, and construction. Among them, production employees account for 48.4%, administrative positions account for 31.1%, and technical positions account for 20.5%. The age distribution is mainly between 20 and 40 years old (accounting for 82.7%), and the educational background is mainly bachelor's degree or above (accounting for 69.7%). The sample structure matches the characteristics of the research subjects to a high degree.

A multiple linear regression model is constructed with the three dimensions of corporate low-carbon climate (cognition, institution, and behavior) as the core variables, and employees' age, education background, and job type as the control variables. The results are shown in **Table 2**.

Table 2. The impact of corporate low-carbon climate on employees' environmental identity.

Variables	Model 1 (Identity Cognition)	Model 2 (Identity Affect)	Model 3 (Identity Behavioral Intention)
Control Variables			
Age	0.03/1.52	0.03/1.17	0.04/1.86
Education Background	0.17/3.17**	0.09/1.66	0.09/1.61
Job Type	0.05/1.18	0.06/1.53	0.13/3.39***
Core Variables			
Cognitive Climate	0.35/5.18***	0.22/3.03**	0.20/3.00**
Institutional Climate	0.19/2.60*	0.25/3.67***	0.20/2.99**
Behavioral Climate	0.12/1.78	0.16/2.26*	0.23/3.49***
Model Fit			
R ²	0.428	0.386	0.392
ΔR^2	0.381***	0.335***	0.347***
F Value	18.36***	15.72***	16.05***

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; β denotes the standardized regression coefficient, t represents the t -statistic; ΔR^2 is the change in R^2 after the inclusion of core variables.

The three dimensions of corporate low-carbon climate (cognitive, institutional, and behavioral) exert significant positive impacts on the three dimensions of employees' environmental identity (identity cognition, identity affect, and identity behavioral intention), presenting distinct characteristics of dimension-matched driving. Among the control variables, education background has a significant positive moderating effect on employees' identity cognition—employees with a bachelor's degree or above show higher absorption efficiency of low-carbon cognition. Job type exerts a more prominent positive moderating effect on identity behavioral intention, with technical positions being more strongly driven by the behavioral climate. Age has no significant impact on the three dimensions of identity and is not a key moderating factor. There are differences in the driving intensity of core variables: the cognitive climate has the strongest driving effect on identity cognition, as the cognitive information conveyed by enterprises through low-carbon concept promotion and knowledge training serves as the core foundation for employees to establish the identity cognition of "environmental stakeholder"; the institutional climate has the most prominent driving effect on identity affect, where clear reward-punishment rules and assessment mechanisms effectively enhance employees' sense of achievement and belonging in low-carbon practices; the behavioral climate has the strongest driving effect on identity behavioral intention, as the low-carbon behavior demonstration by management and colleagues significantly stimulates employees' willingness to actively engage in low-carbon practices.

3.2. Analysis of the negative impact of employees' environmental identity on the corporate low-carbon atmosphere

This section adopts a combination of case data and questionnaire data to verify the feedback effect, with the core reason lying in the differences between the characteristics of the reverse feedback mechanism and research needs compared to positive driving: first, the feedback effect is "lagging and process-oriented"—the upgrading of the corporate climate driven by employees' proactive behaviors based on identity recognition does not appear immediately. It is necessary to capture the complete process of behavior occurrence, mechanism transmission, and effect manifestation through long-term tracking in case studies, avoiding the limitation that quantitative data can only reflect "result correlation" but cannot explain "process logic"; second, the feedback effect exhibits "heterogeneity"—employees from different industries, enterprises, and positions have differences in their feedback methods and paths. Case data can intuitively present this heterogeneity through specific scenarios and examples, making the conclusions more practically valuable; third, the two form a "quantitative + qualitative" complementary verification—reverse regression of questionnaire data can accurately quantify the intensity and significance of the feedback effect, while case data can provide concrete support for the quantitative results, ensuring both the scientificity of the conclusions and the comprehensibility of the mechanism.

Regarding case data, through interviews and on-site observations of Enterprises A, B, and C, a total of 386,000 words of valid qualitative materials were compiled, among which content related to employees' participation in low-carbon climate construction accounted for 29.3%; for questionnaire data, taking each dimension of employees' environmental identity at time *t* as independent variables, each dimension of corporate low-carbon climate at time *t*+1 as dependent variables, and controlling for enterprise scale and industry type, a reverse multiple linear regression analysis was conducted. The results are shown in **Table 3**.

Table 3. Results of reverse regression analysis of employees' environmental identity on corporate low-carbon climate.

Variables	Model 1 (t+1 Cognitive Climate)	Model 2 (t+1 Institutional Climate)	Model 3 (t+1 Behavioral Climate)
Control Variables			
Enterprise Scale	0.09/2.12*	0.12/2.76**	0.08/1.85

Variables	Model 1 (t+1 Cognitive Climate)	Model 2 (t+1 Institutional Climate)	Model 3 (t+1 Behavioral Climate)
Industry Type	0.11/2.23*	0.09/1.88	0.12/2.57*
Core Variables			
Identity Cognition	0.29/3.92***	0.17/2.51*	0.13/1.97*
Identity Affect	0.16/2.28*	0.25/3.53***	0.20/2.79**
Identity Behavioral Intention	0.12/1.64	0.19/2.78**	0.31/4.73***
Model Fit			
R ²	0.375	0.352	0.401
ΔR^2	0.328***	0.301***	0.354***
FValue	16.92***	15.03***	19.24***

Table 3. (Continued)

Note: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; β refers to the standardized regression coefficient, t denotes the t -statistic; ΔR^2 represents the change in R^2 after the inclusion of core variables; $N = 122$.

The three dimensions of employees' environmental identity, namely identity cognition, identity affect and identity behavioral intention, exert significant positive feedback effects on the three dimensions of corporate low-carbon climate—cognitive climate, institutional climate and behavioral climate—in the subsequent period, also demonstrating the characteristic of dimension matching. Among the control variables, enterprise scale has a significant positive moderating effect on the feedback effects on cognitive climate and institutional climate in the subsequent period; large enterprises achieve more prominent feedback effects due to their more refined institutional feedback channels. Industry type exerts a significant positive moderating effect on the feedback effects on cognitive climate and behavioral climate in the subsequent period; employees in the new energy industry have more in-depth low-carbon cognition, thus generating more obvious feedback effects. The core variables show differentiated strengths in their feedback effects: identity cognition has the strongest feedback effect on cognitive climate in the subsequent period, as employees with strong identity cognition will take the initiative to output low-carbon knowledge and enrich the content of corporate cognitive climate; identity affect has the most significant feedback effect on institutional climate in the subsequent period, as employees with profound identity affect will actively feed back institutional loopholes and participate in rule optimization to promote the improvement of institutional climate; identity behavioral intention has the most prominent feedback effect on behavioral climate in the subsequent period, as employees with strong behavioral intention will take the initiative to drive others to practice low-carbon behaviors and strengthen the demonstration effect of corporate low-carbon behaviors.

4. Research conclusions and implications

4.1. Core research conclusions

This study takes enterprises undergoing zero-carbon transition as the research objects, and systematically reveals the laws of synergistic interaction between corporate low-carbon climate and employees' environmental identity through a mixed research method combining case study and questionnaire survey. The core conclusions are as follows:

First, there exists a dimension-matched positive driving mechanism of corporate low-carbon climate on employees' environmental identity. The three dimensions of cognitive climate, institutional climate, and behavioral climate all exert significant positive impacts on employees' environmental identity, but there are differences in their driving priorities. Cognitive climate serves as the core foundation for the formation of employees' identity cognition; by promoting low-carbon concepts and providing knowledge training, it helps

employees establish the identity positioning of "environmental stakeholders", and its driving effect is the most prominent. Institutional climate provides deterministic feedback for employees' low-carbon behaviors through clear reward and punishment rules as well as assessment mechanisms, effectively enhancing employees' sense of achievement and belonging in low-carbon practices, and it has the strongest driving effect on identity affect. Behavioral climate forms a demonstration effect through the low-carbon practices of management and colleagues, significantly stimulating employees' willingness to actively engage in low-carbon behaviors, and its driving effect on identity behavioral intention is the most obvious.

Second, employees' environmental identity has a reverse enabling feedback mechanism on corporate low-carbon climate. The three dimensions of identity cognition, identity affect, and identity behavioral intention can all promote the upgrading of corporate low-carbon climate in the subsequent period, and the priorities of feedback effects show the characteristic of dimension correspondence. Employees with strong identity cognition will take the initiative to output low-carbon knowledge and insights, enriching the content supply of corporate cognitive climate. Employees with profound identity affect, due to their strong sense of belonging to the enterprise's low-carbon goals, will actively feed back institutional loopholes and participate in rule optimization, promoting the continuous improvement of institutional climate. Employees with strong identity behavioral intention will drive others to practice low-carbon behaviors together through their own actions, strengthening the demonstration effect of corporate behavioral climate, and their feedback effect is the most prominent.

Third, the two form a synergistic closed loop through two-way interaction, and the synergistic effect is moderated by multiple factors. The positive driving effect of corporate low-carbon climate provides initial momentum for synergy, while the reverse feedback effect of employees' environmental identity injects sustained driving force into synergy. The cyclic interaction between the two forms a positive cycle of "climate construction — identity reinforcement — climate upgrading", ultimately achieving the synergistic outcome of normalizing employees' low-carbon behaviors and improving the efficiency of enterprises' zero-carbon transition. In terms of moderating effects, employees' education background has a significant impact on the driving effect of cognitive climate on identity cognition, and job type has a significant impact on the driving effect of behavioral climate on identity behavioral intention. The industry attribute and scale of enterprises moderate the intensity of the reverse feedback effect; the cognitive feedback effect of employees in the new energy industry is more obvious, and the institutional feedback effect of large-scale enterprises is more prominent.

4.2. Theoretical contributions

First, it constructs a two-way synergistic mechanism framework based on multiple theoretical foundations, making up for the limitation of one-way cognition in existing research. This study does not subjectively set the two-way relationship, but systematically demonstrates the two-way interaction logic between corporate low-carbon climate and employees' environmental identity with social identity theory and organizational interaction theory as the core supports, combined with the existing research consensus in the field of low-carbon management. Social identity theory provides the basis for "climate driving identity", that is, the organizational environment shapes individual identity through value transmission and norm setting. Organizational interaction theory provides the support for "identity feeding back into climate", that is, individuals participate in the optimization of organizational environment through proactive behaviors. The construction of this theory-supported mechanism breaks through the fragmented limitations of existing research that either focuses on one-way organizational shaping or analyzes individual identity in isolation, and enriches the theoretical system at the intersection of organizational behavior and low-carbon management.

Second, it refines the correlation between variable dimensions and reveals the law of dimension matching, deepening the understanding of the micro-mechanism of interaction between the two. Most existing studies regard corporate low-carbon climate and employees' environmental identity as a single construct, lacking in-depth exploration of the interaction relationship between internal dimensions. This study decomposes corporate low-carbon climate into three dimensions: cognition, institution and behavior, and divides employees' environmental identity into three dimensions: identity cognition, identity affect and identity behavioral intention. Through quantitative analysis, it clarifies the positive driving matching relationships of "cognitive climate—identity cognition", "institutional climate—identity affect" and "behavioral climate—identity behavioral intention", as well as the reverse feedback matching relationships of "identity cognition—cognitive climate", "identity affect—institutional climate" and "identity behavioral intention—behavioral climate", providing a more detailed theoretical perspective for accurately understanding the internal logic of the interaction between the two.

4.3. Practical Implications

Based on the research conclusions, practical implications are proposed from both the enterprise and policy levels to facilitate the implementation of zero-carbon transformation: (1) At the enterprise level: design a "dimension-matching" low-carbon atmosphere construction strategy

Enterprises should optimize the three-dimensional construction of a low-carbon atmosphere in a targeted manner based on the different dimensional needs of employees' environmental identity recognition, avoiding "even-handed application of effort". In terms of cognitive atmosphere construction, regular low-carbon knowledge training, production of industry low-carbon technology manuals, and inviting experts to interpret zero-carbon policies can be adopted to strengthen employees' recognition of low-carbon values. Especially for employees with bachelor's degree or above, technical cognitive content (such as low-carbon technology principles, carbon footprint calculation methods) can be added to enhance their identity recognition foundation. In terms of institutional atmosphere construction, it is necessary to improve low-carbon behavior reward and punishment rules, such as setting up "stepped low-carbon rewards" and establishing "low-carbon system feedback channels", deepening employees' identity emotions through deterministic feedback. In terms of behavioral atmosphere construction, management should be encouraged to take the lead in practicing low-carbon behaviors, and a platform for employees to share their low-carbon behaviors can be established to strengthen employees' identity behavioral intentions through the "behavioral contagion" effect. Especially for technical employees, they can be encouraged to apply low-carbon technologies to work practices and share their experiences.

Enterprises need to value the feedback value of employees' environmental identity recognition and proactively provide channels for employees to participate in atmosphere construction. They can establish a "Low-Carbon Volunteer Group" to recruit employees with strong identity recognition to participate in cognitive atmosphere content design, institutional atmosphere optimization, and behavioral atmosphere promotion. Regularly hold "Low-Carbon Suggestion Meetings" to collect employees' suggestions for improving the low-carbon atmosphere of the enterprise and publicly disclose the feedback and adoption status, stimulating employees' enthusiasm for active participation.

(2) Policy level: Guide enterprises to attach importance to the zero-carbon transformation path of "humanistic synergy"

When promoting zero-carbon transformation among enterprises, government departments should not only provide policy support for the upgrading of low-carbon technologies and the construction of low-carbon facilities, but also pay attention to the synergy between the low-carbon atmosphere in enterprises and

employees' environmental identity recognition, incorporating "humanistic synergy" into the evaluation system of zero-carbon transformation. Special policies can be introduced to provide additional incentives to enterprises that attach importance to the construction of employees' environmental identity recognition; a "communication platform for enterprise low-carbon humanistic construction" can be established to organize enterprises with significant transformation achievements to share experience in the synergy of "atmosphere-identity", such as the technical manual writing mode of enterprise A and the institutional feedback mechanism of enterprise B; differentiated guidance can be provided for enterprises of different industries and sizes, with a focus on guiding the synergy of cognitive atmosphere and identity recognition for enterprises in the new energy industry, and guiding the synergy of institutional atmosphere and identity emotion for large enterprises, helping enterprises accurately grasp the key points of synergy and improve the comprehensive efficiency of zero-carbon transformation.

4.4. Research limitations

Although this study systematically reveals the collaborative mechanism between corporate low-carbon atmosphere and employees' environmental identity, there are still three limitations that need to be addressed in subsequent research:

Firstly, the number of case companies is limited and the industry coverage is relatively narrow, not encompassing industries such as construction, transportation, and service sectors, which are also facing the pressure of zero-carbon transition. This may limit the applicability of the case conclusions across different industries. Future research could broaden the scope of cases to include enterprises from more industries, compare the differences in collaboration mechanisms across different sectors, and enhance the universality of the conclusions.

Secondly, the regional coverage of the sample data is insufficient. Although the questionnaire samples in this study cover four industries, they do not explicitly distinguish regional differences, and regional economic development levels and the implementation strength of zero-carbon policies may affect the construction of a low-carbon atmosphere in enterprises and employees' environmental identity. Future research can add regional variables to analyze the moderating effect of regional factors on the collaborative mechanism, making the conclusions more region-specific.

Conflict of interest

There is no conflict of interest.

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Appendix

1. Measurement Items of Corporate Low-Carbon Climate (1 = Strongly Disagree, 5 = Strongly Agree)

1.1 Cognitive Climate

1. The enterprise often disseminates the concept of low-carbon development through internal announcements, posters and other forms.
2. The company regularly organizes low-carbon knowledge training sessions, lectures or online learning activities.
3. The enterprise clearly conveys the goals and importance of zero-carbon transition to employees.
4. I can easily access low-carbon related policies and knowledge materials issued by the enterprise.

1.2 Institutional Climate

1. The enterprise has formulated clear low-carbon codes of conduct and operational standards.
2. The company has established a special reward mechanism (e.g., bonuses, honorary recognition, etc.) for employees' low-carbon practices.
3. The enterprise has clear restrictive or punitive measures for behaviors such as resource waste and high carbon emissions.
4. Low-carbon performance is incorporated into the employee performance evaluation system.

1.3 Behavioral Climate

1. The enterprise's management takes the lead in practicing low-carbon behaviors in daily work (e.g., turning off lights when leaving, saving paper, etc.).
2. Colleagues around me generally have strong low-carbon awareness and often take the initiative to practice low-carbon behaviors.
3. There are low-carbon related interest groups or volunteer teams within the enterprise with high employee participation.
4. Colleagues share low-carbon tips with each other and supervise each other's low-carbon behaviors.

2. Measurement Items of Employees' Environmental Identity (1 = Strongly Disagree, 5 = Strongly Agree)

2.1 Identity Cognition

1. I consider myself a person who cares about the environment and practices low-carbon behaviors.
2. The identity of a low-carbon practitioner is highly consistent with my self-positioning.
3. I have a clear understanding of the low-carbon responsibilities I should undertake as an "environmental stakeholder".
4. At work, I consciously regulate my behaviors in accordance with low-carbon standards.

2.2 Identity Affect

1. Practicing low-carbon behaviors brings me a strong sense of achievement and satisfaction.
2. I feel a strong sense of belonging and pride when the enterprise achieves its low-carbon goals.
3. I have a profound emotional identification with the enterprise's zero-carbon transition cause.
4. I feel pleased when I see that my low-carbon behaviors have a positive impact on the environment.

2.3 Identity Behavioral Intention

1. I am willing to take the initiative to learn more low-carbon knowledge and skills and apply them to work.
2. I will participate more actively in various low-carbon activities organized by the enterprise in the future.
3. I plan to try more innovative low-carbon practices in my work.
4. I am willing to encourage people around me to practice low-carbon behaviors together.

3. Measurement Items of Control Variables

Age: ☐ 20–30 years old ☐ 31–40 years old ☐ 41–50 years old ☐ 51 years old and above

Education Background: ☐ Senior high school and below ☐ Junior college ☐ Bachelor's degree ☐ Master's degree and above

Job Type: ☐ Production position ☐ Administrative position ☐ Technical position ☐ Others