

THE EVOLUTION OF GREEN DEVELOPMENT POLICY CHARACTERISTICS IN BEIJING-TIANJIN-HEBEI REGION

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Abstract: The green development policies in the Beijing-Tianjin-Hebei region are crucial for promoting coordinated ecological progress. Since the launch of the green development initiative, China's central and local governments have issued over 230 policy documents covering the period from 2006 to 2024. This study employs Latent Dirichlet Allocation (LDA) modeling to analyze these policy texts, revealing rich thematic content with emerging trends like "construction" and "technology". By mapping the evolutionary patterns of these policies, the research provides actionable insights for future policy directions and offers a foundation for refining existing frameworks.

Keywords: Beijing-Tianjin-Hebei; Policy theme; Green development

1 INTRODUCTION

The report of the 20th National Congress proposed accelerating green transformation, clarifying the improvement of fiscal, tax, financial policies, and standard systems supporting green development, as well as the layout for developing green and low-carbon industries. In research on government policy texts, scholars have focused on three aspects in their studies of Beijing-Tianjin-Hebei policies: First, qualitative methods such as content analysis and policy instrument perspectives, including exploration of mechanism innovation and regional policy safeguards[1], identification of knowledge clustering and networks[2], environmental governance policy evaluations[3], analysis of regional innovation system synergy[4]. Second, quantitative methods like bibliometric analysis, though addressing large sample sizes and low content relevance, such as analysis of carbon emission drivers[5], assessment of regional industrial coordination impacts on Hebei's industrial structure[6], and proposal for regional collaborative advancement of dual-carbon goals[7]. Third, explorations into policy text quantification techniques, including investigation into policy themes and network structure characteristics[8].

This study employs data mining and machine learning algorithms to identify policy evolution characteristics and inform targeted policy formulation for future implementation.

2 RESEARCH DESIGN

2.1 Research Approach

This study employs keywords such as "green", "low-carbon", and "circular" to collect data through combined searches. Precise retrieval is conducted at the occurrence positions of relevant sentences to download policy documents meeting requirements. The corpus is segmented using Jieba Library and stop words are removed. Thematic extraction and visualization are performed via Latent Dirichlet Allocation (LDA) model, while TF-IDF is utilized for keyword extraction. Word clouds are generated for thematic content analysis, and statistical analysis of theme-specific terms across different years is conducted. A Sankey diagram is created to explore the evolution of thematic trends.

2.2 Data Sources and Selection

Using the Beida Legal and Regulatory Database, China National Knowledge Infrastructure (CNKI) Legal Database, and official websites of national ministries and commissions as search sources, we conducted searches using two restriction methods: "theme" and "full-text" with keywords such as "green", "low-carbon", and "circular". To ensure the obtained policy texts possess authority and accuracy, three screening principles were adopted: Policy texts should cover as comprehensive a scope as possible; If the title does not contain the keyword, select policy texts where the keyword appears at least three times in the full text; Remove informal documents such as approvals, letters, and announcements, and select policy texts of types including opinions, plans, notices, measures, guidelines, and schedules. Ultimately, 230 policy texts from the period 2006 to 2024 were screened.

2.3 Policy Text Preprocessing

In text preprocessing, the policy lexicon is first imported. The Jieba library is utilized to perform word segmentation on the corpus dataset. The segmented text better reflects semantic information, thereby enhancing the accuracy and interpretability of the topic model. Stop words refer to those that frequently appear in texts but provide no substantial

contribution to the text's theme. By loading a stop word list and removing irrelevant vocabulary, the model's efficiency and accuracy are significantly improved.

2.4 Extraction of Subject Keywords from Policy Text

After the training of LDA topic model, the text keyword extraction method based on TF-IDF is as follows: if a word frequently appears in one article but rarely appears in other articles, this word will be considered as a good representative of the content of the current article.

3 DATA AND ANALYSIS

3.1 Policy Keyword Frequency Analysis

Before conducting a thematic analysis of the Beijing-Tianjin-Hebei green policies, it is essential to identify key policy terms. These are defined as words in policy documents that are directly related to green initiatives. The first step involves establishing a specialized lexicon for Beijing-Tianjin-Hebei green policies, ensuring all entries are closely associated with these initiatives. The preprocessed text is then analyzed using this lexicon to measure keyword frequency and conduct statistical analysis. The resulting frequency statistics are presented in Figure 1.

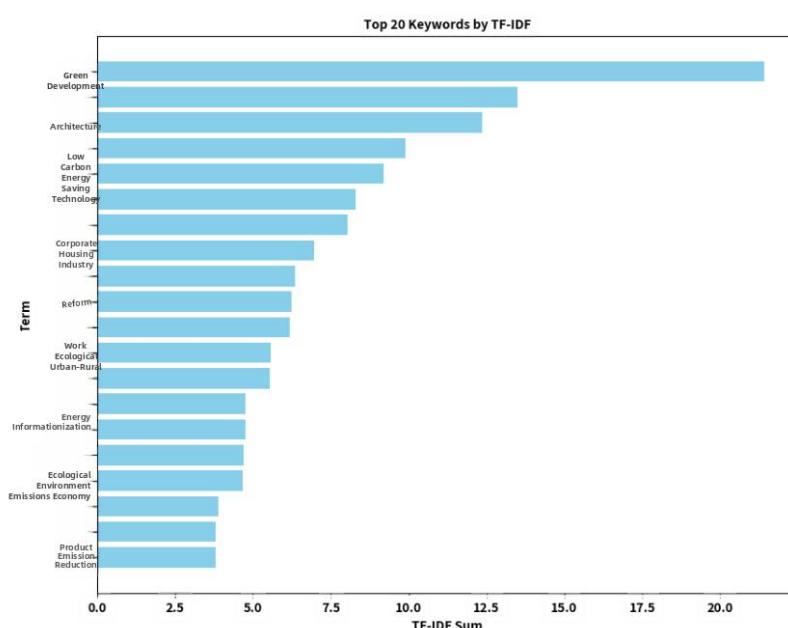


Figure 1 Top 20 High Frequency Words

Among policy keywords, "green" ranks first with the highest TF-IDF score, indicating its frequent occurrence and unique significance in policy documents. This highlights the emphasis on green development and reflects policy inclinations toward environmental protection, energy conservation, emission reduction, and sustainable growth. Subsequent keywords like "development," "construction," and "low-carbon" also show high frequency and importance, involving initiatives such as developing a green economy and reducing carbon emissions. Green development is recognized as a key strategy to enhance ecological and economic benefits. Additionally, terms like "technology," "enterprise," and "ecology" receive high scores, demonstrating that green policies also focus on technological innovation, corporate transformation, and ecological conservation. These policies aim to create an environmentally friendly growth model, emphasizing the harmonious coexistence of environmental protection and economic development while ensuring regional sustainability. This comprehensive strategy forms the cornerstone of a full green transition, laying the foundation for future development. Policy documents showcase the vision of promoting economic growth through environmental protection, establishing a sustainable foundation for long-term development.

3.3 LDA Thematic Analysis

This study will employ the Latent Dirichlet Allocation (LDA) model for thematic analysis across different time periods. After preprocessing to eliminate irrelevant terms and reduce data dimensions, we calculated filtered TF-IDF values to identify policy themes in key provinces. The LDA modeling process utilized Python's Sklearn package. Three methodologies are commonly used to determine the number of LDA topics: similarity-based selection, perplexity-based determination, and empirical approach. This paper selects the optimal topic count based on thematic characteristics across provincial regions.

Table 1 Classification of Green Development Policy Themes in Beijing, Tianjin and Hebei from 2006 to 2011

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
system	popularize	structural readjustment	project	produce
city	highly active	improve	build	product
ability	resource	concrete	family	enterprise
the sources of energy	exploitation	carry out	Hebei	keynote
pyroelectricity	iron and steel	move	building	resource
fire coal	economy	natural gas	accumulation area	build
centrality	produce	characteristic	enterprise	exploitation
develop	technology	be conscious of	green	develop
heat addition	develop	continue	develop	recurrence
build	recurrence	you	estate	economy

A thematic classification of green development policies in the Beijing-Tianjin-Hebei region from 2006 to 2011 was conducted, resulting in five themes with ten corresponding keywords as shown in Table 1. The table reveals: Theme 1 includes keywords like "system" and "city", focusing on energy conservation policies, heating system upgrades, and eco-friendly initiatives; Theme 2 features terms such as "promotion" and "efficiency", emphasizing resource optimization, technological innovation for green energy adoption, and steel industry reforms; Theme 3 encompasses "structural adjustment" and "improvement", highlighting environmental policy implementation and ecological upgrades; Theme 4 involves "projects" and "construction", specifically addressing green building policies in Hebei Province; Theme 5 centers on "production" and "products", involving industrial restructuring and resource transitions toward sustainable development.

Table 2 Classification of Green Development Policy Themes in Beijing, Tianjin and Hebei from 2011 to 2015

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
strengthen	environmental protection	quote	build	examine
set up	push on	technology	develop	storm fortifications
air pollution	strengthen	work	Publicity Week	organism's habits
rectify	pollute	standard	conduct propaganda	Ten thousand acres
put in order	organism's habits	housing	organization	accomplish
Beijing-Tianjin-Hebei Region	keynote	be in progress	mine	green
build	building	build	environmental protection	engineering
enterprise	develop	project	low-carbon	forestation
the end of the year	build	building	energy conservation	build
straw	environment	green	activity	make green by planting trees

The thematic classification of green development policies in the Beijing-Tianjin-Hebei region from 2011 to 2015 is presented in Table 2, which categorizes five themes with ten corresponding keywords. The table reveals: Theme 1 (keywords including "strengthen" and "air pollution") focuses on air quality improvement, straw burning control, corporate carbon emission policies, and carbon compliance measures. Theme 2 (keywords like "construction" and "pollution") emphasizes environmental protection initiatives, ecological remediation efforts, and green building standards. Theme 3 (keywords such as "citation" and "technology") addresses technological innovation and policy refinement in sustainable construction. Theme 4 (keywords including "construction" and "initiation") involves eco-awareness campaigns, environmental organization support, and mining project regulations. Theme 5 (key terms like "evaluation" and "campaign") highlights poverty alleviation strategies with green initiatives, afforestation programs, and coordinated ecological-economic development.

Table 3 Classification of Green Development Policy Themes in Beijing, Tianjin and Hebei from 2015 to 2019

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
administer	work	develop	ecological condition	kilojoule
standard	machine-processed	push on	electric power generation	enterprise
accomplish	classify	conduct propaganda	renewable sources of energy	engineering
build	hospital	activity	enterprise	exploitation
appraise	build	reform	school	kilocalorie
work	rubbish	low-carbon	quantity of electricity	carbon emission reduction
discharge	quality	build	city	standard coal
enterprise	build	green	green	achievement
green	centrality	develop	power	kilogram
building	patient	energy conservation	business	technology

The thematic classification of green development policies in the Beijing-Tianjin-Hebei region from 2015 to 2019 is summarized in Table 3, comprising five major themes with ten corresponding keywords. The table reveals: Theme 1 includes keywords like "governance" and "standards," addressing the establishment of an evaluation system for green development construction in the Beijing-Tianjin-Hebei region, standardization of policies, and policy implementation. Theme 2 features terms such as "classification" and "hospitals," focusing on environmental protection and healthcare policy formulation and development. Theme 3 contains keywords like "initiate" and "promote," representing reform measures and publicity campaigns for green development in the region. Theme 4 encompasses "ecological environment" and "renewable energy," advocating corporate leadership and low-carbon initiatives by social organizations while emphasizing the importance of ecological conservation and renewable energy utilization. Theme 5 includes keywords like "engineering projects" and "emission reduction," indicating phased achievements through pilot policies and new technologies implemented by enterprises.

Table 4 Classification of Green Development Policy Themes in Beijing, Tianjin and Hebei from 2019 to 2024

Theme 1	Theme 2	Theme 3	Theme 4	Theme 5
administer	be interrelated	put into effect	develop	reform
pollute	energy conservation	administer	work	duty
keynote	about	ecological condition	city	division of labour with individual responsibility
limited company	have sth. to do with	keynote	push forward	people's government

develop	enterprise	develop	energy conservation	bring forth new ideas
discharge	building	push on	push on	push forward
accomplish	low-carbon	protect	build	push on
power	develop	strengthen	develop	estate
business	project	build	building	build
enterprise	green	organism's habits	green	develop

A thematic classification of all green development policies in the Beijing-Tianjin-Hebei region during 2019-2024 yielded results as shown in Table 4. The analysis categorized these policies into five themes, each containing 10 key terms. The table reveals: Theme 1 includes keywords like "governance," "pollution," "key areas," and "enterprises," indicating policy priorities for corporate pollution control and low-carbon environmental trading. Theme 2 features terms such as "projects," "green initiatives," "enterprises," and "energy conservation," highlighting policies promoting low-carbon development in construction sectors. Theme 3 contains phrases like "strengthening," "ecological conservation," and "key areas," underscoring the urgency of environmental governance and systematic implementation of ecological protection measures. Theme 4 encompasses keywords including "cities," "energy efficiency," and "construction," focusing on urban development strategies for low-carbon growth. Theme 5 incorporates terms such as "government bodies," "innovation," "responsibilities," and "promotion," emphasizing coordinated policy execution through clear division of duties to ensure orderly implementation and drive industrial innovation.

3.4 Analysis of the Thematic Dimension of Policy

3.4.1 Policy theme characterization

Based on the characteristics of green development policies in the Beijing-Tianjin-Hebei region, the research on green development policies is divided into four phases: The first phase (2006-2011) focused on infrastructure construction and circular economy, introducing policies to promote economic industrialization, emphasize resource recycling, and improve heating system efficiency. This phase aimed to establish infrastructure, enhance energy efficiency, and advance circular economy applications. The second phase (2011-2016) prioritized housing energy conservation and urban-rural balance, continuing policies to optimize environmental standards for housing construction, improve energy efficiency, and reduce carbon emissions. This phase facilitated urban-rural integration and accelerated green transformation in the construction sector. The third phase (2016-2019) emphasized technological innovation and institutional reform, implementing policies for eco-friendly technology adoption, reforming systems to promote green production and consumption, and driving R&D and dissemination of environmental technologies. The fourth phase (2019-2024) focused on ecological protection and energy optimization, addressing environmental conservation and energy structure improvement, reducing pollution, enhancing energy efficiency, and advancing sustainable development goals. Using the thematic confusion degree calculation method in Equation 1.1, we determined the optimal number of themes for each policy phase in the Beijing-Tianjin-Hebei region, with specific results shown in Figure 2.

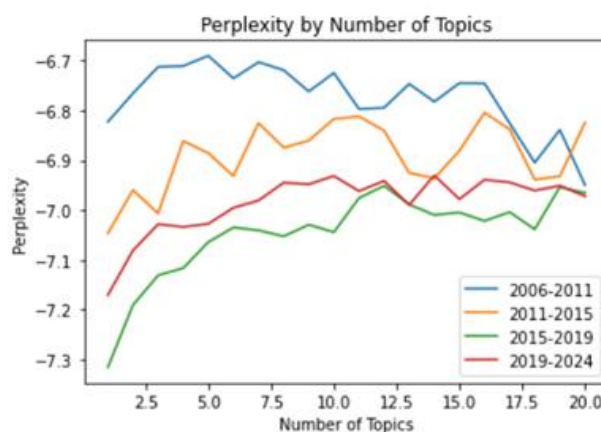


Figure 2 Perplexity by Number of Topics

As shown in Figure 2, confusion degree analysis, the optimal number of policy themes for China's Beijing-Tianjin-Hebei green policies followed a cyclical pattern: 4 themes from 2006 to 2011, 5 themes from 2011 to

2016,6 themes from 2016 to 2019, and 6 themes again from 2019 to 2024. To comprehensively evaluate quality and stability metrics, this study conducted manual optimization of policy themes, as detailed in Table 5.

Table 5 Theme Distribution by Stage

Window of time	Optimal topics (items)	Hashtag
2006-2011	4	Energy supply and urban heating Efficient resource utilization Circular economy and key enterprises Green buildings and industrial clusters Air pollution control and regulation
2011-2015	5	Environmental protection and ecological construction Green building standards and low-carbon environmental protection publicity activities Ecological greening project Enterprise emission control Garbage classification and hospital construction
2015-2019	6	Low-carbon development and publicity Green Power Trading Quality improvement and innovation Energy saving technology and architecture Electricity trading and pollution control Energy saving technology and low carbon development
2019-2024	6	Ecological and environmental protection Urban energy conservation transformation Green innovation and industrial development Forest greening and administrative licensing

According to the above distribution of green policy themes in Beijing-Tianjin-Hebei, the green development policy themes in Beijing-Tianjin-Hebei can be classified into six categories:

- (1) Energy supply and urban heating, including energy supply, urban heating, thermoelectricity, coal burning and other sub-themes;
- (2) High efficiency resource utilization, including sub-themes such as resource utilization, steel, economy, production and technological development;
- (3) Circular economy and key enterprises, including sub-themes such as circular economy, key enterprises, industrial clusters, project construction, etc.;
- (4) Air pollution control and rectification, including air pollution control, rectification, enterprise emissions, garbage classification and other sub-themes;
- (5) Green building and ecological protection, including sub-themes such as green building, ecological protection, ecological construction, and building standards;
- (6) Low-carbon environmental protection publicity and activities, including low-carbon environmental protection publicity, energy-saving technology, green innovation, low-carbon development and other sub-themes.

From a temporal perspective, the green development policy framework for the Beijing-Tianjin-Hebei region has evolved through four distinct phases spanning 2006 to 2024: Infrastructure and Circular Economy Development, Housing Energy Efficiency and Urban-Rural Balance Development, Technological Innovation and Institutional Reform, and Ecological Conservation and Energy Optimization. This progression reflects the continuous refinement and upgrading of regional green policies. Spatially, the initiative covers the entire area, providing comprehensive policy support and guidance across technology R&D, standard-setting, infrastructure construction, and market regulation to promote coordinated green development. In terms of content, the framework embodies three core principles--innovation-driven growth,coordinated advancement, and open development--while emphasizing low-carbon, eco-friendly, and sustainable development directions. It highlights energy conservation, emission reduction, and ecological protection goals, charting a clear vision for regional green development.

4 CONCLUSION

Through categorization and analysis of green development policy themes in the Beijing-Tianjin-Hebei region from 2006 to 2024, it is evident that policy focus has evolved into increasingly diversified and sophisticated areas. Initially emphasizing energy structure optimization and ecological conservation, subsequent policies expanded to encompass multiple domains including green building practices, corporate sustainable production, and government responsibility allocation, demonstrating significant enhancement in policy comprehensiveness and detail. Early policies primarily concentrated on promoting efficient resource utilization and structural adjustments, while later measures shifted toward concrete implementation strategies and continuous improvement initiatives such as establishing governance evaluation systems, enhancing waste sorting and processing, and advancing low-carbon technology adoption. This progression reflects policymakers' ongoing efforts to refine policy frameworks in response to complex environmental challenges and achieve higher standards of green development.

The evolution trend of the green development policy themes in the Beijing-Tianjin-Hebei region mainly focuses on two directions: one is energy conservation and environmental protection, mainly including themes such as "energy-saving technology and low-carbon development" and "green innovation and industrial development"; the other is ecological protection, mainly including themes such as "ecological environment protection" and "forest greening and administrative licensing". It is worth noting that the two evolution trends of "energy conservation and environmental protection" and "ecological protection" are in line with China's green development strategic measures, indicating that the evolution trend of the green development policy themes in the Beijing-Tianjin-Hebei region is consistent with the national development strategy, reflecting the direction and goal of regional green development. Therefore, in the future, the green development policy in the Beijing-Tianjin-Hebei region should adhere to the two major development directions of "energy conservation and environmental protection" and "ecological protection", strengthen energy-saving technological innovation and ecological protection measures, and thereby promote high-quality and sustainable development in the Beijing-Tianjin-Hebei region.

COMPETING INTERESTS

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