

# QUANTITATIVE EVALUATION OF CHINA'S ENERGY REVOLUTION POLICIES UNDER THE DUAL CARBON TARGETS

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(Received 28<sup>th</sup> Oct 2025; accepted 22<sup>nd</sup> Jan 2026)

**Abstract.** The energy revolution serves as a strategic foundation for promoting high-quality development in China. It not only bears on national energy security and the attainment of the "dual carbon" goals but also acts as a key driver for accelerating the comprehensive green transformation of the economy and society. In the face of increasingly complex energy transition tasks, systematically evaluating the design quality and implementation effectiveness of energy revolution policies holds significant practical importance. The Policy Modeling Consistency (PMC) index model, which accommodates multi-dimensional indicators and objectively reflects the internal coherence of policy content, provides a scientific tool for the quantitative evaluation of energy policies. This study employs the PMC index model to systematically assess key energy revolution policies issued at the national level and in selected representative provinces since 2014. The aim is to identify the strengths and weaknesses of existing policies and to provide references for subsequent policy optimization. The findings reveal that current policies are predominantly rated as "acceptable" or "good", indicating considerable room for improvement in terms of policy objective setting, coordination of policy tool mixes, and content comprehensiveness. Future policy formulation should enhance policy independence and systematicness, refine relevant legal and regulatory frameworks, and optimize the configuration of policy tools. These efforts are essential to elevate the energy revolution policy system from merely "acceptable" to "highly effective", thereby better supporting the synergistic realization of high-quality development and the "dual carbon" goals.

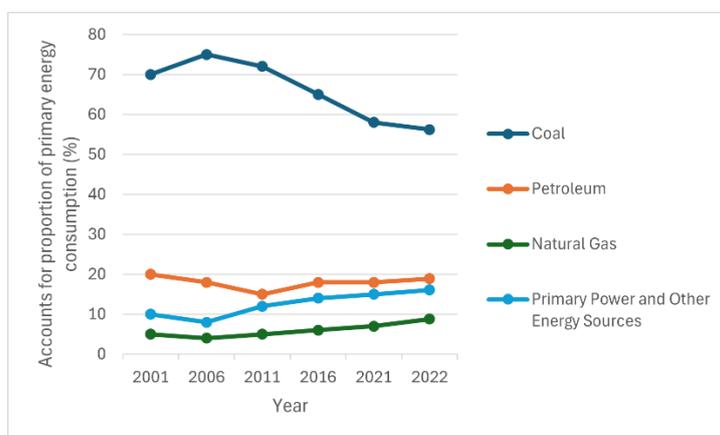
**Keywords:** *energy revolution, energy reform, policy quantification, PMC index model, dual carbon goals*

## Introduction

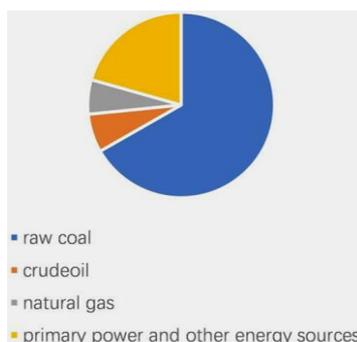
### *Research background and significance*

During the 75th United Nations General Assembly (UNGA) on 22 September 2020, President Xi Jinping declared that China would strive to reach peak carbon emissions around 2030 and pursue carbon neutrality by 2060. This commitment established a long-term roadmap for the country's climate and energy transition strategy. "Carbon peaking" signifies reaching the highest point of carbon dioxide emissions, while "carbon neutrality" involves offsetting greenhouse gas emissions through measures such as afforestation and energy conservation. The introduction of the "dual carbon" strategy provides clear guidance for China's socio-economic transformation and represents a critical contribution to global efforts against climate change. The 20th National Congress report highlighted that integrating green and low-carbon principles into both economic and social development processes is a key pathway towards achieving high-quality growth. Given China's resource endowments, strategic priorities include controlling fossil fuel consumption, promoting clean, low-carbon, and efficient energy utilization, accelerating the energy revolution, improving clean coal utilization, intensifying oil and gas exploration, and building a modern energy system.

China is among the world's major consumers of energy and coal, and remains a significant importer of crude oil. Preliminary data from the National Bureau of Statistics demonstrate that the country's total energy consumption in 2022 equated to 5.41 billion tons of standard coal... Clean energy sources... constituted 25.9%, representing a 0.4 percentage-point rise from 2021 (Figs. 1 and 2). From 2014 to 2022, China's energy structure underwent remarkable transformation: coal's share of total energy consumption dropped from 66.0% to 56.2%, while renewable energy (hydropower, nuclear, wind, solar) increased from 16.1% to 21.8%, and natural gas rose from 5.6% to 8.8% (National Development and Reform Commission of the People's Republic of China, 2022). At the provincial level: (1) Shanxi Province: As a coal-rich region and national comprehensive energy revolution pilot, its renewable energy installed capacity accounted for 40.25% of total installed capacity in 2022, a 15.3 percentage-point increase from 2019 (the pilot's launch year); (2) Shandong Province: Wind power installed capacity reached 19.42 million kilowatts in 2021, 3.2 times that of 2014, and nuclear power projects (e.g., Haiyang Nuclear Power Plant) were put into operation successively; (3) Qinghai Province: Clean energy installed capacity exceeded 90% of total capacity in 2022 (44.68 million kilowatts), with solar and wind power generation accounting for 35% of total electricity output—up from 18% in 2014. Data from the China Statistical Yearbook indicate that fossil fuels continue to dominate China's energy structure, with coal and oil collectively representing nearly 75%, highlighting the extensive challenges in energy structure transformation.



**Figure 1.** Energy consumption proportion in selected years (2001, 2006, 2011, 2016, 2021, 2022)



**Figure 2.** Primary energy production proportion in 2021. Data Source: China Statistical Yearbook 2022 (provides comprehensive historical time-series energy data since 1978, ensuring consistency of long-term trend analysis)

According to the Western environmental impact model (I=PAT), the level of environmental impact (I) is determined by the combined effects of population (P), affluence (A), and technology (T). Building on this framework, Japanese scholar Yoichi Kaya proposed the “Kaya Identity” in 1989, which expresses carbon dioxide emissions as the product of population, per capita GDP, energy intensity of GDP, and the carbon intensity of energy consumption (Kaya, 1989). This implies that achieving carbon peak targets requires slowing population growth, lowering GDP per capita growth rates, improving energy efficiency, decreasing energy consumption intensity through industrial transformation, and replacing traditional fossil energy with renewable alternatives toward lowering emission intensity. Consequently, altering China’s energy landscape and promoting energy transitions are crucial steps to achieving the “dual carbon” objectives. Energy revolution policies aim to optimize the existing energy structure and foster clean, low-carbon, secure, and efficient energy development.

### ***Literature review***

The Chinese energy revolution constitutes a strategic imperative, shaped by profound transformations in the global energy landscape and mounting domestic resource and environmental constraints. Internationally, the U.S. shale gas revolution has significantly reconfigured global energy geopolitics, while rapid advancements in new energy technologies have accelerated the global transition toward green, low-carbon development (Yang et al., 2020). Domestically, China’s resource endowment—characterized by “abundant coal, scarce oil, and insufficient natural gas”—has resulted in steadily rising import dependence for oil and gas; concurrently, its carbon-intensive energy structure imposes substantial pressure to meet national emission reduction targets (Liu et al., 2022; Wang, 2021). Shen and Xue (2011) underscore that energy security necessitates coordinated efforts across both supply- and demand-side dimensions. Earlier, Guan and He (2007) observed that energy security has evolved into a multidimensional challenge, encompassing geopolitical dynamics, international trade, and critical infrastructure—including energy transportation corridors.

In 2014, President Xi Jinping proposed five requirements for promoting the energy revolution: revolutionizing energy consumption, establishing diversified supply systems, advancing technological innovation, reforming institutional mechanisms, and strengthening international cooperation (Chang & Huang, 2017; Zou et al., 2023). He (2014) delineates the dual pillars of the energy revolution: the consumption revolution, aimed at curbing inefficient and unsustainable energy use; and the supply revolution, oriented toward clean, low-carbon energy system transformation. Lin (2018) further posits that this transition represents an inevitable pathway for China to navigate the critical inflection point associated with the environmental Kuznets curve. Under the impetus of the “dual carbon” goals (i.e., peak carbon emissions by 2030 and carbon neutrality by 2060), non-fossil energy—particularly solar photovoltaics—is projected to assume a dominant role in the national energy mix. Correspondingly, coal and oil consumption are expected to decline markedly; by 2060, the share of new energy in total primary energy consumption is anticipated to exceed 80% (Wang, 2021; Zou et al., 2024). Empirical analysis by Liu et al. (2022) reveals that between 2012 and 2019, China achieved a 28.99% reduction in energy intensity, sustained optimization of its energy structure, and a 61.25% improvement in total-factor energy productivity—signifying a historic shift in both energy production and consumption paradigms. Such efficiency gains have provided robust underpinning for high-quality economic development (Wei &

Shen, 2007). Zhang et al. (2024) emphasized talent development and technological innovation in coal industry reform. Zhang (2022) pointed out that natural gas could serve as a driving force for a new phase of the energy revolution in the Sichuan–Chongqing region. Scholars from the Institute of Fiscal Science under the Ministry of Finance carried out a study exploring policy pathways to advance China's energy transition during the 13th Five-Year Plan period (Cheng et al., 2024). They stressed the importance of policy integration and innovation, suggesting measures such as establishing a market-based energy trading system, clarifying governmental energy management responsibilities, and improving energy fiscal and taxation policies. Existing quantitative studies on energy revolution policies typically focus on specific aspects rather than a comprehensive policy perspective. For instance, Li and Hu (2026) quantitatively analyzed new energy vehicle subsidies, emphasizing increased funding and public-to-private transport transition strategies. Etukudoh et al. (2024) quantitatively assessed carbon reduction policies, identifying deficiencies in policy functions, incentives, effectiveness, and scope of impact. Collectively, these scholarly contributions establish a rigorous theoretical and empirical foundation for the quantitative policy evaluation undertaken in this study.

The PMC (Policy Modeling Consistency) index model was proposed by Estrada (2011) based on the Omnia Mobilis hypothesis, emphasizing that various relevant variables should be fully considered in policy evaluation to avoid one-sidedness. By constructing a multi-input-output table and using binary assignment to balance indicators, the model can calculate the policy consistency index and draw PMC surfaces to visually display the strengths and weaknesses of policies, offering advantages such as comprehensive evaluation, strong objectivity, and high visualization (Zhang & Geng, 2015). In recent years, the PMC model has been widely applied in domestic policy evaluation: in science and technology innovation policies, Zhang and Geng (2015) first introduced and validated its effectiveness; Hu et al. (2020) used it to evaluate robot industry policies; Xie and Wang (2024) analyzed 5G strategic emerging industry policies. In talent and governance policies, Hu and Zhang (2021) assessed fault tolerance and error correction policies, revealing the asynchrony between policy quality and implementation; Yao et al. (2024) constructed a “goal-tool-effectiveness” framework to evaluate digital government construction policies; Hu et al. (2024) conducted a comparative study on science and technology talent policies in Jiangsu, Zhejiang, and Guangdong. Additionally, the model has been applied in housing rental (Dong et al., 2020), scientific data opening (Song et al., 2021), and digital economy (Cai et al., 2021). The PMC model is suitable for this study because it can systematically evaluate the multi-dimensional content consistency of energy revolution policies under the “dual carbon” goals, reveal structural characteristics and optimization spaces in policy design, and provide a scientific basis for policy improvement.

A recent study by Yan et al. (2025) employed the Policy Modeling Consistency (PMC) index model to evaluate China's carbon emission reduction policies, covering 10 national and local policies across administrative tiers. While both studies adopt the PMC framework, key differences exist: (1) Research object: Yan et al. (2025) focused on carbon reduction policies, whereas this study specifically targets energy revolution policies—a broader concept encompassing consumption, supply, technology, institution, and international cooperation; (2) Regional scope: Yan et al. (2025) included policies from 5 provinces/municipalities (Shanxi, Beijing, Shandong, Jiangsu, Shanghai), while this study selects 3 representative provinces with distinct resource endowments (coal-rich Shanxi as the only national comprehensive energy revolution pilot, high-emission Shandong, and renewable energy-rich Qinghai) to explore region-specific policy

adaptation; (3) Core focus: This study emphasizes policy independence, cross-sector coordination, and legal framework improvement—dimensions less addressed in Yan et al. (2025)'s analysis of carbon reduction policy effectiveness. The novelty of this study lies in: (1) Systematically evaluating energy revolution policies' completeness from the Dual Carbon strategy's inception (2014) to 2023; (2) Highlighting the role of comprehensive pilot regions (Shanxi) in policy innovation; (3) Proposing targeted legal and institutional safeguards for energy transition, complementing existing carbon reduction policy research.

Currently, research on China's energy revolution predominantly focuses on the concept's intrinsic significance or specific implementation pathways, with limited attention to policy analysis. Existing policy research largely adopts a macroscopic perspective of policy implementation, often neglecting detailed evaluations of policy coherence and rationality. To address this gap, this paper utilizes a quantitative textual analysis approach, employing the objective and scientifically robust PMC Index Model. By constructing a comprehensive evaluation framework for energy revolution-related policies, this study systematically examines the scientific validity and rationality of national and local policies issued in China. The research seeks to capture the current status and trends of China's energy revolution, clarify the quality and characteristics of existing policies, and ultimately provide targeted recommendations and strategic insights for future policy formulation, optimization, and adjustment.

### ***Research content and methods***

The PMC index model is based on the Omnia Mobilis hypothesis, which states all things are interconnected, and hence no relevant variable should be ignored. Variables should be selected broadly to measure the internal consistency of policies accurately (Zhang & Geng, 2015). The PMC model was first proposed by Estrada (2011) and later localized for Chinese policy evaluation by Baogui et al. (2022), featuring systematic and objective assessment of policy consistency. The specific steps include: (1) collecting and conducting frequency analysis of policy texts to determine variables and parameters; (2) constructing a multi-input-output table; (3) calculating PMC indices; and (4) plotting PMC surfaces. The PMC index model has two key advantages over other common policy evaluation models: first, it employs data mining methods, reducing subjective bias by extensively selecting secondary variables directly derived from policy texts; second, it covers multiple policy dimensions, clearly identifying policy strengths and weaknesses, providing targeted recommendations for future policy adjustments.

Since President Xi Jinping first introduced the concept of the energy revolution in 2014, a series of relevant policies have been issued. With the establishment of the “dual carbon” targets, the pace of policy issuance accelerated significantly. This paper systematically compiles relevant policies since 2014, utilizing the objective PMC Index Model to identify current policy shortcomings and limitations comprehensively. Analysis shows that, both at national and local levels, existing policies are relatively limited in number, often narrowly focused on specific sectors, and lacking comprehensive coverage. Notably, comprehensive policies are predominantly concentrated in Shanxi Province—the only comprehensive energy revolution reform pilot region in China. Local policies generally exhibit greater comprehensiveness, providing more practical and detailed measures compared to national-level policies. These findings offer valuable insights for improving and implementing China's future energy revolution policies and hold practical significance for industrial transformation and upgrading.

The primary objective of this study is to systematically evaluate the scientific validity and rationality of national and local energy revolution policies in China using the PMC index model. By identifying policy strengths, weaknesses, and structural deficiencies, this study aims to provide targeted recommendations for enhancing policy independence, comprehensiveness, cross-sector coordination, and legal safeguards—ultimately supporting the achievement of national Dual Carbon goals.

## Materials and methods

### *Current status analysis of China's energy revolution policies*

Since General Secretary Xi Jinping first introduced the concept of the energy revolution in 2014, all policy documents analyzed in this study were published thereafter. National-level energy revolution policies can be broadly categorized into two stages: the formation stage (2014–2020) and the development stage (2021–present). The concept of an “energy revolution” was first introduced in 2014, marking a new stage in China’s energy governance, while 2020 became a milestone year with the announcement of the national Dual Carbon targets. This formative phase largely overlapped with the closing period of the 12th Five-Year Plan and extended into the early to middle years of the 13th. Efforts to enhance energy efficiency had already been prioritized in the 11th Five-Year Plan, which established binding objectives for reducing energy intensity and pollutant emissions. Building on this foundation, the 12th Five-Year Plan adopted the “dual control” mechanism—targeting both energy intensity and total consumption—to promote adjustments in the national energy structure. By the 13th Five-Year Plan, China’s energy strategy had evolved from a focus on securing supply to an active approach emphasizing demand-side management and total consumption control.

The existing policies show that the quantity of energy revolution-related policies at the national level is still relatively limited. Particularly during the initial stage, only three policies were issued, each narrowly targeting specific energy types or sectors, lacking comprehensive perspectives, and consequently limiting their effectiveness in achieving energy revolution objectives. However, this situation improved significantly in the second stage, characterized by an accelerated pace of policy release and enhanced comprehensiveness. A key factor in this improvement was the introduction of the “dual carbon” strategy, reflecting inevitable developments in energy transition trends. Current policies during the second stage include comprehensive guiding documents as well as targeted implementation pathways for specific industries or groups. As these trends continue, it is expected that future policies will become increasingly refined and mature (as shown in *Table 1*).

**Table 1.** Summary of national-level energy revolution policies and their stages

Stage	Policy name	Issuing authority	Date
Formation stage	“Guiding Opinions on Advancing the Construction of New Energy Microgrid Demonstration Projects”	National Energy Administration (NEA)	2015.07.13
	“Guiding Opinions on Developing Straw Gasification and Clean Energy Utilization Demonstration Projects”	National Development and Reform Commission (NDRC), Ministry of Agriculture and Rural Affairs (MARA), National Energy Administration (NEA)	2017.12.28

	“Notice on the Establishment of a Monitoring and Evaluation Mechanism for Clean Energy Demonstration Provinces (Regions) (Trial)”	National Energy Administration (NEA)	2018.01.19
Development stage	“Implementation Opinions on Accelerating Rural Energy Transformation Development to Support Rural Revitalization”	Ministry of Agriculture and Rural Affairs (MARA), National Energy Administration (NEA), National Rural Revitalization Administration (NRRA)	2021.12.29
	“Opinions on Strengthening Institutional Mechanisms and Policies for a Green and Low-Carbon Energy Transition”	National Development and Reform Commission (NDRC), National Energy Administration (NEA)	2022.1.30
	“Action Plan for Standardization Enhancement of Energy Carbon Peak and Carbon Neutrality”	National Energy Administration (NEA)	2022.09.20
	“Action Plan (2023–2025) for Accelerating Oil and Gas Exploration, Development, and Integration with New Energy”	National Energy Administration (NEA)	2023.2.27
	“Construction Plan for Rural Energy Revolution Pilot Counties”	National Energy Administration (NEA), National Rural Revitalization Administration (NRRA), Ministry of Agriculture and Rural Affairs (MARA), Ministry of Ecology and Environment (MEE)	2023.3.15

Source: Peking University Law Database

This study also selected three representative provinces—Shanxi, Shandong, and Qinghai—to further illustrate regional policy contexts and developments due to their distinctive resource endowments and energy strategies. Shanxi Province, renowned for its abundant coal reserves, is China’s sole comprehensive energy revolution reform pilot province. Shandong Province, an economic powerhouse in northern China, has the country’s largest carbon emissions. Qinghai Province, rich in renewable resources such as wind, solar, and hydropower, has rapidly developed its clean energy sector.

Shanxi Province, a prominent coal-producing region, is the only comprehensive pilot province for energy revolution reform in China. Coal resources are abundant, covering approximately 62,000 km<sup>2</sup> (40.4% of provincial area), with proven reserves of about 270.9 billion tons, constituting 17.3% of national coal reserves. Additionally, coal-bed methane reserves amount to approximately 8.31 trillion cubic meters. Given the decline of the coal industry post-2013 and the national shift towards ecological sustainability, Shanxi has actively pursued comprehensive energy reforms since becoming a pilot region in 2019. Major progress has been achieved in several areas, including advancements in clean coal technologies, pioneering reforms in the electricity market, and a marked expansion of renewable energy capacity. As a result, clean energy now represents 40.25% of China’s total installed power capacity. Shanxi has also significantly reduced energy intensity by 16% cumulatively from 2019 (the start of the comprehensive pilot reform) to 2022.

Shandong Province, a leading economic power in northern China, is characterized by significant heavy industrialization, particularly refining and electrolytic aluminum industries. Consequently, Shandong is China’s largest emitter of carbon dioxide,

accounting for approximately 9% of national emissions, with 44% from the power sector alone. In response, Shandong has prioritized green transformation, becoming a pioneer in establishing national green low-carbon development zones. The province has greatly expanded its wind power capacity to 19.42 million kilowatts by 2021 and accelerated nuclear power development. Furthermore, Shandong proactively promotes its hydrogen industry, establishing the nation's first provincial-level hydrogen industry development plan. The province also leads in lithium battery storage, developing five major industrial bases.

Qinghai Province, located in western China, boasts considerable renewable energy potential due to its advantageous geographic conditions on the Qinghai-Tibet Plateau. Qinghai's non-fossil energy consumption has consistently exceeded 40%, significantly above the national average since 2018. Over recent years, Qinghai has excelled in integrated clean energy systems, notably achieving over 90% clean energy in total installed power capacity (44.68 million kilowatts). Qinghai successfully developed the world's first ultra-high-voltage green electricity transmission projects and established China's first fully renewable-powered data center. Moving forward, Qinghai continues promoting diversified renewable energy technologies and storage methods, transforming its rich renewable resources into strategic industrial advantages.

Overall, reviewing policy stages reveals that the current policies exhibit improvements over time regarding comprehensiveness and practicality. Nevertheless, further enhancements in policy independence, comprehensiveness, cross-sector collaboration, and supportive legislative measures remain necessary to fully realize the goals of China's energy revolution.

## ***Empirical analysis***

### *Data source*

Since the PMC Index Model focuses on the analysis of policy documents, selecting sources that are both authoritative and publicly available becomes a critical step to ensure relevance and reliability. The policy texts used in this research were mainly collected from the Peking University Fabao Database and the official website of China's National Energy Administration. The selected policy documents were issued after the introduction of the energy revolution concept in 2014. To maintain data quality, only formal policy documents—including notifications, guidelines, decisions, programs, plans, and schemes—were selected, while informal documents such as replies and letters were excluded. Policies that had become invalid or irrelevant to the research objective were also eliminated. Ultimately, the analysis dataset comprised 8 national-level policies and 70 local-level policies.

### *Variable selection and parameter identification*

The collected policy documents were aggregated as analytical samples and subjected to segmentation using the ROST CM6.0 software, followed by keyword frequency analysis. The segmented keywords were sorted according to their frequencies in descending order. Considering the research emphasis on the energy revolution, generic terms such as “energy revolution” and “energy reform,” along with other terms that lacked substantial analytical significance, were removed, resulting in 80 significant keywords retained for detailed analysis (*Table 2*).

**Table 2.** Frequency statistics of keywords in 78 energy revolution policy texts (8 national + 70 local)

NO.	Keywords	Frequency	NO.	Keywords	Frequency	NO.	Keywords	Frequency
1	Energy	3885	28	Natural Gas	747	55	Clean	494
2	Construction	2894	29	Innovation	746	56	Encouragement	477
3	Development	2852	30	Country	715	57	Security	476
4	Project	2800	31	System	689	58	Promotion	461
5	New Energy	2004	32	Active	679	59	Power Station	461
6	Photovoltaic	1625	33	Mechanism	664	60	Scale	448
7	Technology	1536	34	Service	642	61	Environment	447
8	Promote	1485	35	Market	627	62	New Construction	441
9	Clean energy	1466	36	Improvement	594	63	Solar Energy	440
10	Utilization	1370	37	Establishment	593	64	Region	432
11	Enterprise	1354	38	Framework	587	65	Implementation	429
12	Electricity	1330	39	Enhancement	583	66	Facilitation	426
13	Power generation	1298	40	Policy	582	67	Scheme	425
14	Grid	1205	41	Domain	578	68	Industry	422
15	Development	1195	42	Comprehensive	573	69	Target	417
16	Planning	1117	43	Demonstration	572	70	Heating	411
17	Green	1060	44	Rural	560	71	NDRC	408
18	Resources	1015	45	Improvement	557	72	Coal	398
19	Accelerate	908	46	Management	551	73	Operation	396
20	Promote	870	47	Energy Storage	551	74	Biomass	380
21	Unit	840	48	Guarantee	545	75	Conditions	378
22	Engineering	814	49	Investment	534	76	Transition	372
23	Key	802	50	Consumption	530	77	Government	372
24	Strengthen	788	51	Distributed	519	78	Renewable Energy	369
25	Implementation	764	52	Transformation	517	79	13th Five-Year Plan	368
26	Wind Power	762	53	Realization	510	80	Demand	368
27	Application	761	54	Low-carbon	498			

Source: Compiled by the authors

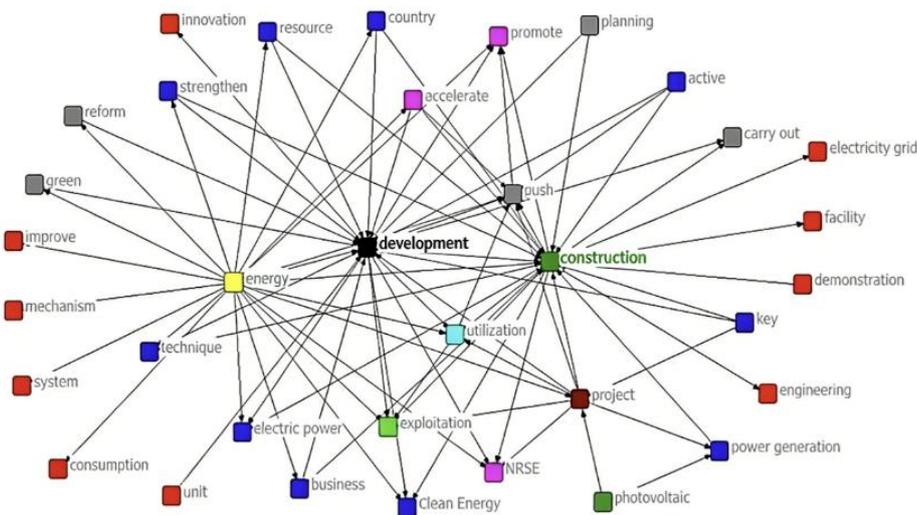
Subsequently, a high-frequency keyword co-occurrence network (*Fig. 3*) was constructed to visualize keyword relationships and identify policy focal points clearly. Drawing from frequency analysis results and previous literature, particularly the studies conducted by scholars like Zhang Yongan and Zhu Zhen (Zhang and Geng, 2015; Zhu and Lu, 2022), this research identified 10 primary variables and 40 secondary variables. Each primary variable encompasses various secondary variables as summarized in *Table 3*.

**Table 3.** Indicator variable correspondence table

Primary variable	Secondary variables
P <sub>1</sub> Level of Impact	P <sub>1.1</sub> National Level; P <sub>1.2</sub> Local Level
P <sub>2</sub> Policy Duration	P <sub>2.1</sub> Short term (within 3 years); P <sub>2.2</sub> Medium term (3–5 years); P <sub>2.3</sub> Long term (beyond 5 years)
P <sub>3</sub> Issuing Authority	P <sub>3.1</sub> NDRC; P <sub>3.2</sub> Energy Administration; P <sub>3.3</sub> People's Government; P <sub>3.4</sub> People's Congress and Standing Committee; P <sub>3.5</sub> Other Departments
P <sub>4</sub> Authority Level	P <sub>4.1</sub> Laws; P <sub>4.2</sub> Administrative Regulations; P <sub>4.3</sub> Departmental Rules; P <sub>4.4</sub> Normative Documents; P <sub>4.5</sub> Industry Regulations

P <sub>5</sub> Policy Perspective	P <sub>5.1</sub> Rural; P <sub>5.2</sub> Urban
P <sub>6</sub> Involved Industries	P <sub>6.1</sub> Coal; P <sub>6.2</sub> Oil; P <sub>6.3</sub> Natural Gas; P <sub>6.4</sub> Primary Electricity and Other Energies
P <sub>7</sub> Functional Domain	P <sub>7.1</sub> Economic; P <sub>7.2</sub> Social; P <sub>7.3</sub> Political; P <sub>7.4</sub> Ecological Civilization; P <sub>7.5</sub> Technology
P <sub>8</sub> Policy Functions	P <sub>8.1</sub> Demonstration Projects; P <sub>8.2</sub> Energy Planning; P <sub>8.3</sub> Mechanism Establishment; P <sub>8.4</sub> Technological Development; P <sub>8.5</sub> Development and Utilization; P <sub>8.6</sub> Innovation Leadership; P <sub>8.7</sub> Implementation Supervision
P <sub>9</sub> Guarantee and Incentives	P <sub>9.1</sub> Legal Guarantees; P <sub>9.2</sub> Technical Guidance; P <sub>9.3</sub> Investment Subsidies; P <sub>9.4</sub> Talent Development; P <sub>9.5</sub> Platform Construction; P <sub>9.6</sub> Data Support
P <sub>10</sub> Public Accessibility	No secondary variables

Source: Compiled by the authors



**Figure 3.** High-frequency keyword co-occurrence network. Source: Compiled by the authors. Generated by ROST CM6.0 and Origin 2023

After identifying the variables, the parameters for the PMC Index Model were set. Based on established theoretical principles, this study assumes equal importance across all secondary variables; hence, uniform weights are assigned within the multi-input-output table. The parameters for each secondary variable were quantified using a binary coding system: a value of 1 was assigned if the policy explicitly matched the criteria associated with a particular secondary variable or contained relevant keywords; otherwise, a value of 0 was assigned.

### Construction of the multi-input–output matrix

The Multi-Input–Output Matrix (MIOM) serves as a multidimensional analytical framework designed to quantify and evaluate energy revolution policies within the PMC Index model. This framework has been widely applied in policy quantitative evaluation studies, with proven effectiveness in capturing policy complexity and internal consistency (Cheng et al., 2024; Estrada, 2011). Within this framework, equal weighting is assigned to each primary and secondary variable. The MIOT constructed for this study is presented in *Table 4*.

**Table 4.** Multi-input output table

<b>P<sub>1</sub></b>	<b>P<sub>2</sub></b>
P <sub>1.1</sub> P <sub>1.2</sub>	P <sub>2.1</sub> P <sub>2.2</sub> P <sub>2.3</sub>
P <sub>3</sub>	P <sub>4</sub>
P <sub>3.1</sub> P <sub>3.2</sub> P <sub>3.3</sub> P <sub>3.4</sub> P <sub>3.5</sub>	P <sub>4.1</sub> P <sub>4.2</sub> P <sub>4.3</sub> P <sub>4.4</sub> P <sub>4.5</sub>
P <sub>5</sub>	P <sub>6</sub>
P <sub>5.1</sub> P <sub>5.2</sub>	P <sub>6.1</sub> P <sub>6.2</sub> P <sub>6.3</sub> P <sub>6.4</sub>
P <sub>7</sub>	P <sub>8</sub>
P <sub>7.1</sub> P <sub>7.2</sub> P <sub>7.3</sub> P <sub>7.4</sub> P <sub>7.5</sub>	P <sub>8.1</sub> P <sub>8.2</sub> P <sub>8.3</sub> P <sub>8.4</sub> P <sub>8.5</sub> P <sub>8.6</sub> P <sub>8.7</sub>
P <sub>9</sub>	P <sub>10</sub>
P <sub>9.1</sub> P <sub>9.2</sub> P <sub>9.3</sub> P <sub>9.4</sub> P <sub>9.5</sub> P <sub>9.6</sub>	P <sub>10</sub>

Source: Compiled by the authors

*PMC index calculation and PMC surface plotting*

The calculation of the PMC Index follows four systematic stages:

- ① Develop a Multi-Input–Output Matrix based on clearly defined primary and secondary indicators.
- ② Assign binary values (0 or 1) to each secondary variable, following established criteria: a variable is assigned the value 1 if explicitly mentioned or implied through relevant keywords in the policy text; Otherwise, a value of 0 is assigned. The scores for the primary indicators are then computed using the following formula.
- ③ Calculation of primary variable scores using *Equation 3*, where P<sub>i</sub> denotes the score of primary variable, P<sub>ij</sub> represents the assigned binary value of the secondary variable j under primary variable i, n denotes the total count of secondary indicators associated with primary indicator i.

$$P \sim N[0,1] \tag{Eq.1}$$

$$P = \{PR : [0 \sim 1]\} \tag{Eq.2}$$

$$P_i = \sum_{j=1}^n \frac{P_{ij}}{T(P_{ij})} \tag{Eq.3}$$

$$PMC = \left[ \begin{array}{l} P_1 \left( \sum_{a=1}^2 \frac{P_{1i}}{2} \right) + P_2 \left( \sum_{a=1}^3 \frac{P_{2i}}{3} \right) + P_3 \left( \sum_{a=1}^5 \frac{P_{3i}}{5} \right) + \\ P_4 \left( \sum_{a=1}^5 \frac{P_{4i}}{5} \right) + P_5 \left( \sum_{a=1}^2 \frac{P_{5i}}{2} \right) + P_6 \left( \sum_{a=1}^4 \frac{P_{6i}}{4} \right) \\ + P_7 \left( \sum_{a=1}^5 \frac{P_{7i}}{5} \right) + P_8 \left( \sum_{a=1}^7 \frac{P_{8i}}{7} \right) + P_9 \left( \sum_{a=1}^5 \frac{P_{9i}}{5} \right) + P_{10} \end{array} \right] \tag{Eq.4}$$

④ Aggregate the primary variable scores to derive the PMC Index. After calculating the PMC Index, policies are classified according to defined scoring intervals, as presented in *Table 5*.

**Table 5.** *PMC policy grading criteria*

Grade	PMC score interval
Excellent	8–10
Good	6–8
Qualified	4–6
Unqualified	0–4

This grading criterion is consistent with the universal standards for PMC index application proposed by Estrada (2011) and Baogui et al. (2022), which have been adopted in over 50 policy evaluation studies in fields such as environmental governance, technological innovation, and energy transition (Estrada, 2011; Baogui et al., 2022; Yan et al., 2025). Source: Compiled by the authors

Additionally, PMC surface plotting visually represents PMC Index calculation results. The PMC surface is constructed in a three-dimensional space derived from a third-order matrix, clearly demonstrating policy evaluation outcomes. Considering this study includes ten primary variables and the specific characteristics of the variable ‘policy disclosure,’ the latter was excluded from PMC surface plotting. The mathematical expression for PMC surface plotting is given by:

$$PMCsurface = \begin{bmatrix} P_1 & P_2 & P_3 \\ P_4 & P_5 & P_6 \\ P_7 & P_8 & P_9 \end{bmatrix} \quad (\text{Eq.5})$$

Through these methodologies, this paper systematically evaluates the scientific soundness and rationality of national and local energy revolution policies in China.

## Results

### *Selection of evaluation objects*

The PMC index model requires selecting as many relevant variables as possible. Thus, this study does not select policies based solely on policy categories or validity periods. Instead, it comprehensively considers these aspects and selects the most representative policy texts from various periods and administrative levels for quantitative analysis. *Tables 6* and *7* list the selected national and local policies, respectively.

**Table 6.** *Summary of selected national-level policies*

Code	Policy name	Issuing authority	Date
P1	“Guiding Opinions on Advancing the Construction of New Energy Microgrid Demonstration Projects”	NEA	2015.07.13

P2	“Action Plan (2023–2025) for Accelerating Oil and Gas Exploration, Development, and Integration with New Energy”	NEA	2023.02.27
P3	“Construction Plan for Rural Energy Revolution Pilot Counties”	NEA, NRRRA, MARA, MEE	2023.03.15

Source: Peking University Law Database

**Table 7.** Summary of selected local-level policies

Code	Policy name	Issuing authority	Date
P4	“Decision of Shanxi Provincial People’s Congress on Supporting and Guaranteeing the Comprehensive Pilot Reform of the Energy Revolution”	Standing Committee of the People’s Congress of Shanxi Province	2019.09.27
P5	“Shandong Province 2018–2028 Plan on New Energy Industry Growth”	Shandong Province People’s Government	2018.09.17
P6	“Action Plan for Building Qinghai as a National Clean Energy Industrial Highland (2021–2030)”	Qinghai Province People’s Government, National Energy Administration, Standing Committee of the People’s Congress of Qinghai Province	2021.08.12

Source: Peking University Law Database

### Consistency analysis of national-level energy revolution policies

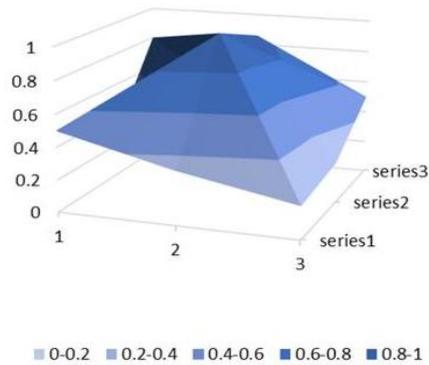
This section examines the internal consistency of national-level policies P1, P2, and P3. *Table 8* shows PMC scores for these policies: 5.64, 5.80, and 5.73, respectively, all classified as qualified. According to the calculation results in *Figures 4–6*, *Table 8*, and *Equation 6*, compared to the average PMC index of six policies, these three national-level policies scored relatively lower. Specifically, the lower scores were mainly due to limited coverage in involved industries, functional domains, policy functions, and incentives. Policy P1 primarily supports electricity sector reforms without clearly defined roles in legal supervision or practical measures. Policy P2 predominantly impacts technology and ecological civilization, resulting in lower scores in the domain of influence, despite better performance in other aspects. Policy P3, focusing on rural energy, scored relatively low in guarantees and incentives. A common issue among these policies is that most energy revolution policies were issued by single agencies such as the National Development and Reform Commission (NDRC), the National Energy Administration (NEA), or the Ministry of Ecology and Environment (MEE), lacking multi-department coordination.

**Table 8.** Summary of PMC indexes for national-level policies

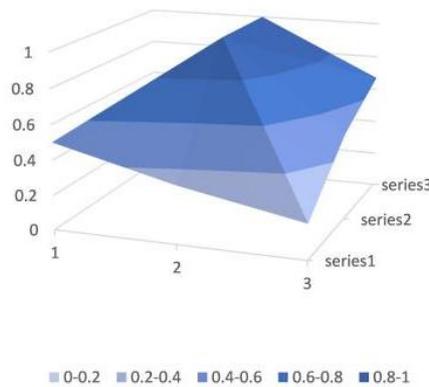
	P1	P2	P3	Average of policies
P <sub>1</sub>	0.50	0.50	0.50	0.50
P <sub>2</sub>	0.33	0.33	0.33	0.33
P <sub>3</sub>	0.20	0.20	0.40	0.27
P <sub>4</sub>	0.20	0.20	0.20	0.20
P <sub>5</sub>	1.00	1.00	0.50	0.83
P <sub>6</sub>	0.25	0.50	0.50	0.42
P <sub>7</sub>	0.80	0.40	0.80	0.67

P <sub>8</sub>	0.86	1.00	1.00	0.95
P <sub>9</sub>	0.50	0.67	0.50	0.56
P <sub>10</sub>	1.00	1.00	1.00	1.00
PMC Score	5.64	5.80	5.73	5.72
Concave Index	3.36	3.20	3.27	3.28

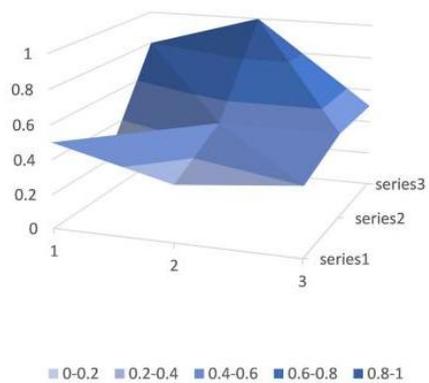
Source: Compiled by the authors



**Figure 4.** PMC surface plot (Policy 1). Source: Compiled by the authors



**Figure 5.** PMC surface plot (Policy 2). Source: Compiled by the authors



**Figure 6.** PMC surface plot (Policy 3). Source: Compiled by the authors

$$P1 = \begin{bmatrix} 0.5 & 0.33 & 0.2 \\ 0.2 & 1 & 0.25 \\ 0.8 & 0.86 & 0.5 \end{bmatrix}, P2 = \begin{bmatrix} 0.5 & 0.33 & 0.2 \\ 0.2 & 1 & 0.5 \\ 0.4 & 1 & 0.67 \end{bmatrix}, P3 = \begin{bmatrix} 0.5 & 0.33 & 0.4 \\ 0.2 & 0.5 & 0.5 \\ 0.8 & 1 & 0.5 \end{bmatrix} \quad (\text{Eq.6})$$

**Comparative analysis of typical provincial energy revolution policies**

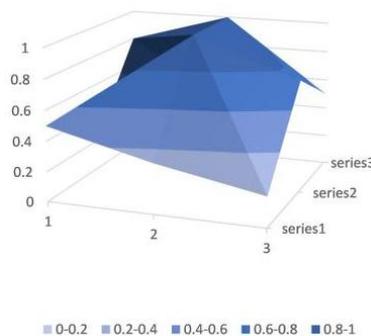
This section evaluates the internal consistency of local-level policies P4, P5, and P6. According to the calculation results in *Figures 7–9*, *Table 9* and *Equation 7*, these policies obtained PMC scores of 6.28, 6.20, and 6.60 respectively, indicating a good performance overall. Compared to the average PMC index across all six policies, local policies scored higher due to their greater detail and practicality. Similar to national-level policies, involved industries, policy functions, and guarantees and incentives strongly influenced their PMC scores. Unlike national policies, these local policies were primarily issued by provincial People’s Congresses or governments.

**Table 9.** Summary of PMC indexes for local-level policies

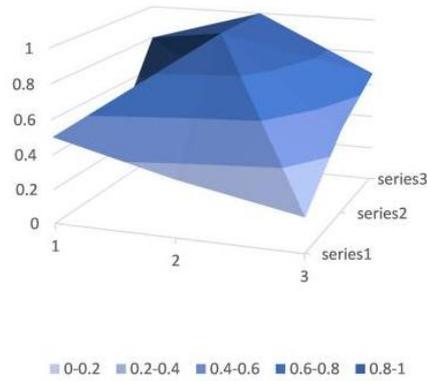
	P4	P5	P6	Average of policies
P <sub>1</sub>	0.50	0.50	0.50	0.50
P <sub>2</sub>	0.33	0.33	0.33	0.33
P <sub>3</sub>	0.20	0.20	0.60	0.33
P <sub>4</sub>	0.20	0.20	0.20	0.20
P <sub>5</sub>	1.00	1.00	1.00	1.00
P <sub>6</sub>	0.75	0.50	0.50	0.58
P <sub>7</sub>	0.80	0.80	0.80	0.80
P <sub>8</sub>	1.00	1.00	1.00	1.00
P <sub>9</sub>	0.50	0.67	0.67	0.61
P <sub>10</sub>	1.00	1.00	1.00	1.00
PMC score	6.28	6.20	6.60	6.36
Concave index	2.72	2.80	2.40	2.64

Source: Compiled by the authors

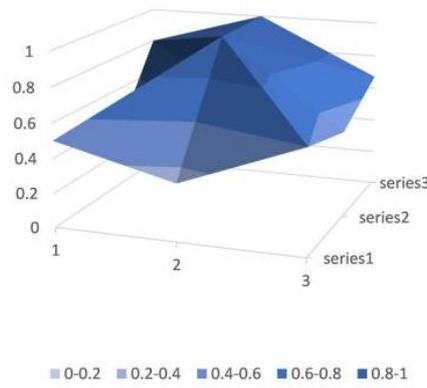
Policy P4 from Shanxi Province supports comprehensive energy revolution pilot reforms, capitalizing on its energy endowment and industry foundation to promote industrial transformation and upgrading. Despite its concise nature, policy P4 demonstrated strong coverage across industries except for petroleum, reflecting Shanxi’s resource base. However, it scored lower in guarantees and incentives, covering only technical guidance, talent cultivation, and platform construction.



**Figure 7.** PMC surface plot (Policy 4). Source: Compiled by the authors



**Figure 8.** PMC surface plot (Policy 5). Source: Compiled by the authors



**Figure 9.** PMC surface plot (Policy 6). Source: Compiled by the authors

$$P4 = \begin{bmatrix} 0.5 & 0.33 & 0.2 \\ 0.2 & 1 & 0.75 \\ 0.8 & 1 & 0.5 \end{bmatrix}, P5 = \begin{bmatrix} 0.5 & 0.33 & 0.2 \\ 0.2 & 1 & 0.5 \\ 0.8 & 1 & 0.67 \end{bmatrix}, P6 = \begin{bmatrix} 0.5 & 0.33 & 0.6 \\ 0.2 & 1 & 0.5 \\ 0.8 & 1 & 0.67 \end{bmatrix} \quad (\text{Eq.7})$$

Policy P5, issued by Shandong Province, presents the development blueprint for the new energy industry covering the period 2018–2028. While scoring the lowest among the three local policies, the gap was minimal, mainly due to lower scores in industry coverage, primarily focusing on new energy rather than traditional fossil fuels.

Policy P6 from Qinghai Province achieved the highest PMC score among all evaluated policies, largely due to multi-agency issuance, enhancing its authority and comprehensive nature. It performed consistently well across all evaluated dimensions.

## Discussion

### *Policy effectiveness in the context of dual carbon goals*

This study’s evaluation results (national policies: qualified; local policies: good) align with Yan et al. (2025)’s findings that China’s low-carbon policies generally achieve “qualified” to “good” ratings. However, energy revolution policies exhibit unique characteristics: local policies (e.g., Qinghai’s Action Plan for Clean Energy Industrial Highland) score higher than national policies due to their targeted adaptation to regional

resource endowments. For example, Qinghai's policy leverages its plateau solar/wind resources to prioritize renewable energy integration, while Shanxi's policy focuses on clean coal technology and electricity market reform—reflecting the importance of region-specific policy design (Li et al., 2024).

### ***Key policy shortcomings and causes***

The main deficiencies identified (single-department issuance, narrow sectoral coverage, insufficient legal guarantees) are rooted in two factors: (1) Institutional fragmentation: Most national policies are issued by single agencies (e.g., NEA) without inter-ministerial coordination, leading to overlapping or conflicting measures (Klüser et al., 2024); (2) Legal framework lag: Unlike the EU's Renewable Energy Directive, China lacks a unified legal document for energy revolution, resulting in weak enforcement of policy targets (Umoh et al., 2022). Additionally, the low political domain scores indicate that energy revolution policies have not been fully integrated into local government performance evaluation systems, limiting their implementation intensity (Alsaid et al., 2024).

### ***Research limitations and future directions***

This study has three limitations: (1) Regional representativeness: Selecting 3 provinces may not fully reflect the diversity of China's energy structure (e.g., coastal vs. inland regions); (2) Dynamic evaluation: The cross-sectional analysis cannot capture policy evolution over time; (3) Qualitative complement: Quantitative PMC scores lack insights into policy implementation effects. Future research could: (1) Expand the sample to 10+ provinces with distinct economic and energy characteristics; (2) Adopt a longitudinal design to evaluate policy changes pre- and post-2020 (the Dual Carbon announcement year); (3) Combine interviews with local policymakers to supplement quantitative results with qualitative insights.

### **Conclusion**

Local-level policies generally demonstrate higher PMC index scores compared to national-level policies due to their greater practicality and detail. However, all evaluated policies exhibit notable shortcomings: (1) Policies typically originate from single departments without multi-sector legislative coordination; (2) Policies focus narrowly on specific sectors, limiting comprehensive coverage; (3) Policies have minimal influence in political domains; (4) Guarantees and incentives are significantly insufficient, particularly legal guarantees. Given the developmental stage of China's energy revolution, current policies emphasize specificity over comprehensiveness. Future energy revolution policies should enhance their autonomy, comprehensiveness, sectoral coverage, and improve the legislative framework.

Firstly, enhance policy independence, comprehensiveness, and cross-sector coordination. Presently, most policies lack an integrated framework, resulting in fragmented implementation and limited efficacy. Future policies should clearly define responsibilities, strengthen inter-departmental collaboration, and establish comprehensive frameworks that cover multiple sectors comprehensively.

Secondly, establish and refine the supporting legal framework. The absence of robust legal guarantees significantly restricts policy effectiveness, hindering the achievement of

the “dual carbon” objectives. Formulating a coherent legal system to support policy implementation is crucial for ensuring the effectiveness of energy revolution initiatives.

Thirdly, enhance policy transparency and public accessibility. Current policies seldom involve extensive public participation or transparent information disclosure mechanisms, potentially restricting policy effectiveness. Future energy revolution policies should prioritize transparency, foster broader public participation, and ensure effective information dissemination and feedback mechanisms.

Future research should further address several key areas to enrich the quantitative evaluation of energy revolution policies. Firstly, subsequent studies could incorporate dynamic evaluation approaches, assessing how policies evolve over time and their long-term impacts on energy transitions. Secondly, considering regional disparities, future studies could conduct detailed comparative analyses across different geographical contexts and economic development levels to provide targeted policy insights. Additionally, deeper explorations into policy interactions and cumulative effects among different policy levels and sectors would offer valuable insights. Future studies may incorporate qualitative approaches—such as interviews or case analyses—to complement the quantitative PMC framework, enabling a more comprehensive assessment of policy performance and its practical relevance.

**Acknowledgements.** This work was supported by the Youth Foundation for Humanities and Social Sciences Research of the Ministry of Education “Research on the Multidimensional Synergistic Mechanism and Common Prosperity Effect of Eco-Compensation Driving the Value Realization of Ecological Products” (Approval No.:25YJCZH324 ).

**Conflict of interests.** The authors declare that there are no conflicts of interest related to this article.

**Data availability statement.** The data that support the findings of this study are available upon reasonable request from the corresponding author.

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