

Research on the Green Consumption Development Based on Fuzzy Comprehensive Evaluation—A Case Study of the Middle and Lower Reaches of the Yangtze River

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Abstract. Studying the development and influencing factors of green consumption plays a guiding role in building a strong country in China and achieving carbon neutrality. On this basis, this paper first constructs the first, second and third-level indicators of green consumption development with 15 third-level indicators. Then, the analytic hierarchy process (AHP) is used to assign weights to the indicators. Finally, the score of green consumption development in provinces and cities is measured and compared by the fuzzy comprehensive evaluation. As a result, it has the greatest impact on the operating income of high-tech enterprises and local fiscal environmental protection expenditure in Shanghai, Jiangsu, Anhui, Zhejiang, Hubei and Hunan provinces. Jiangsu Province has the best development, while Hunan Province has the worst one. Some suggestions are also put forward to strengthen residents' awareness and enterprises' innovative production.

Keywords: Green Consumption Development; Influencing Factors; Analytic Hierarchy Process; Fuzzy Comprehensive Evaluation; Middle and Lower Reaches of the Yangtze River.

1. Introduction

In the early stage of China's economic development, due to the insufficient attention paid to the damage caused by economic development to the environment, the current environmental problem has been one of the most important problems in China. In 2022, the number of people affected by natural disasters in China was 112.678 million, which triggered the direct economic losses up to 238.65 billion yuan [1]. China's collective leadership is laying more emphasis on environmental issues. Based on the report of the 20th National Congress of the Communist Party of China proposed by President Xi, "China should spare no effort to advocate green consumption and promote the formation of green and low-carbon productions and lifestyles." [2] With the Yangtze River as the cradle of the Chinese nation, the development of the Yangtze River Economic Belt is intertwined with the national development. According to the Green and High-quality Development Index of the Yangtze River Economic Belt (2023) Report, "the proportion of the total economic output of the 11 provinces and cities along the Yangtze River Economic Belt in the whole China increased from 45.1% in 2015 to 46.5% in 2022, contributing more than 50% to the national economic growth. In the systematic evaluation of development capabilities featuring environmental protection and high quality, 16 cities in the middle and lower reaches of the

Yangtze River are within the top 20." [3] However, during the green economic development in the middle and lower reaches of the Yangtze River, there are still some problems such as severe water ecological environment, high proportion of heavy chemical industry, and imperfect coordinated development mechanism. In a word, it is of great significance to measure green consumption in the middle and lower reaches of the Yangtze River. On this basis, 15 indexes of the first, second and third levels are constructed. Then, the AHP indexes aim to assign weights. Finally, the fuzzy comprehensive evaluation is conducted to score the green consumption in the middle and lower reaches of the Yangtze River, and explore the differences of green consumption in this region, so as to provide suggestions for the government.

2. Literature Review

Research on Influencing Factors of Green Consumption

Dat DuyNguyen [4] used a structural equation model to analyze the influencing factors of green consumption, which found that government policies, environmental awareness, risk perception, purchase demand and product economy all had a positive impact on green consumption decisions. Therefore, it is proposed that the legal framework of green consumption should be formulated

and improved to promote the market and encourage and form green consumption habits. Mark R. Gleim et al. [5] conducted qualitative interviews, questionnaires and experiments to analyze the influencing factors of green consumption. As a result, the price and professional knowledge are the key factors to prevent the purchase of green products. Therefore, retailers had better formulate strategies to detail the contributions that individual consumers can make in solving environmental problems. Krittinee Nuttavuthisit and John Thøgersen [6] who combined qualitative and quantitative methods found that consumer trust is indispensable for establishing a market for reputable products (such as “green” products), especially when they are expensive. Thus, the need to manage consumer trust is regarded as a prerequisite for a market of green products. Kirtika Deo and Abhnil Prasad [7] used a questionnaire survey to collect data and analyzed it through factor analysis and a structural equation model. It is found that functional value, social value, emotional value and conditional value have vital influences on green energy consumer behavior. Therefore, they suggest carrying out educational activities for young people and emphasizing the functions and environmental benefits of green energy.

Dong Huizhong and Zhao Yanmin [8] used the entropy method, exploratory spatial data analysis and spatial Durbin model to analyze the influencing factors of green consumption. As a result, technological innovation and talent introduction have positive spillover effects, while industrial structure and urbanization have inhibitory effects. Therefore, they call for formulating policies and strengthening regional cooperation and coordination based on local energy consumption. Xie Chi, He Yaxing and Mao Zhonggen [9] using the two-stage Bayesian model averaging found that economic growth is the main driving force, and investment and urbanization have a pulling effect, while R&D investment has a negative impact in the early stage. Therefore, they encourage the upgrading of green consumption from aspects of production, consumption and environment. Xiong Ping, Zhao Zhaoxia and Chen Hongying [10] applied a binary Logistic regression model to analyze the influencing factors of green consumption. As a result, the age, education, price and brand of green products were important influencing factors. Thus, they are required to strengthen the demonstration effect of society, increase the supply of green products by enterprises, and improve the institutional system through the government. Zhao Xiaodi, Fu Jiayan and Pang Xinsheng [11] used a structural equation model (SEM) to make fitting corrections through generalized least squares (GLS). It is found that individual responsibility, policies and product trust have positive effects, while economic factors and product prices hinder green purchasing behavior. Hence, some suggestions are put forward to attract consumers to purchase by reducing the tax and regulating the price of green products.

2.1 Research on the Development Trend of Green Consumption

According to Michal Patak, Lenka Bransk, Zuzana Pecinova, et al. [12], unsustainable consumption worldwide leads to environmental problems, which stimulates consumer interest in environmental problems and demand for green products, prompting enterprises to launch green products. Rulia Akhtar, Sayema Sultana, Muhammad Mehedi Masud, etc. [13] found that with the rise of environmental awareness and the emergence of the green consumption concept in the 1970s, different countries and regions have their distinctive influencing factors. Follow-up research keeps exploring relevant influencing factors, including the comparison of different income groups, etc. In addition, the research continues to develop and improve from theoretical and practical aspects. When it comes to the development of green consumption research conducted by Diego Costa Pinto, Walter Meucci Nique, Marcia Maurer Herter, etc. [14], there is a trend from focusing on the influence of values and identity (i.e. self-transcendence intention affects green consumption more when personal identity is prominent) to expanding the research direction (including studying the interaction of other intention types). Maria J. Montoya-Villalobos [15] found that because some traditional commodity consumption is harmful to the environment, environmental awareness is enhanced, and the green commodity market comes into being with growth. Meanwhile, related research further develops from emphasizing different determinants of green consumption to exploring the uncertainty of green commodity benefits and the impact of attitudes on green consumption.

According to Ding Zhihua [16], China’s current consumption is changing from traditional to green consumption mode. Moreover, the promotion and popularization of green consumption in survival consumption such as food, clothing, housing and transportation manifests China’s green consumption structure, and the role of green consumption in development consumption represented by education and entertainment is still small. Chen Ying [17] found that China’s green consumption maintains a growing trend, the concept is becoming more popular, and relevant policies are constantly introduced. However, there are problems on the supply side, consumption side and infrastructure. In addition, digital consumption has the risk of “carbon lock-in” when promoting green consumption, and the public has some misunderstandings about green consumption. Feng Ye [18] believed that China’s green consumption developed under the concept of green development. Although it encounters challenges such as lack of consumption awareness in the development process, with the increasing residents’ income and the change of concepts, green consumption has developed in some aspects. Thus, promoting the upgrading of green consumption by multiple paths in the future is of importance, such as increasing residents’ income, integrating the Internet and service industry, and realizing the green development of traditional industries. According to Chen Zhixuan and Jian Zhaoquan [19], China’s green consumption development grew slowly.

During 2014-2021, the coupling and coordination with the constantly improved digital economy, and the overall coupling reached a high-quality stage with steady development.

2.2 Literature Review

In a word, foreign scholars pay more attention to exploring how consumers' characteristics on green consumption make a difference from the perspective of individual consumers, and put forward more suggestions for enterprises and individual consumers. Chinese scholars prefer macro-level research, such as regional economic development, industrial structure, technological innovation and other perspectives to analyze the impact on green consumption, with suggestions more around the comprehensive role of government, society and enterprises. However, few scholars evaluate the regional differences in green economy, and the timeliness of the data is not competitive. On this basis, the data is first normalized (standardized). Then, the AHP aims to give the index weights. Finally, the fuzzy comprehensive evaluation is used to assess the

development of green consumption in the middle and lower reaches of the Yangtze River as a whole, so as to explore the differences in the development of different regions.

3. Analytic Hierarchy Process

3.1 Preliminary Screening of Indicators and Data Sources

According to Table 1, the first-level indicator is the development of green consumption. There are four second-level indicators, including consumption structure, environmental factors, economic factors and scientific and technological factors. In addition, there are 15 three-level indicators, including the average number of electric mopeds owned by every 100 urban households at the end of the year, the average number of cars owned by every 100 urban households at the end of the year, solar water heater area, gasoline consumption, etc.

Table 1 Indicators of Influencing Factors of Green Consumption

First-Level Indicators	Second-Level Indicators	Third-Level Indicators	Units
Overall Development of Green Consumption	Consumption Structure	Average of number electric mopeds owned by every 100 urban households at the end of the year	Vehicle
		Average number of cars owned by every 100 urban households at the end of the year	Vehicle
		Solar water heater area	10,000 Square Meters
		Gasoline consumption	10,000 Tons
		Consumption of electric power	Billion Kilowatt Hours
	Environmental Factors	Number of nature reserves	1
		Discharge of municipal sewage	10,000 Cubic Meters
		Total amount of urban domestic water	10,000 Cubic Meters
		Area of planted forest in that year	Thousand Hectares
		Consumption of urban residents	Yuan
	Economic Factors	Consumption of rural residents	Yuan
		Total retail sales of consumer goods	100 Million Yuan
		Local fiscal protection expenditure	100 Million Yuan
			/
	Technological Factors	Number of high-tech enterprises	
		Business income of high-tech enterprises	100 Million Yuan

The sources of data in this paper are the China Statistical Yearbook, China Macroeconomic Database, China Environment Database, China Energy Database, National Economic and Social Development Statistical Bulletin of Province, China Science and Technology Database, the National Nature Reserve Directory, with the 2022 as the year of the data.

3.2 Analytic Hierarchy Process Construction

3.2.1 Analytic Hierarchy Model Construction

The analytic hierarchy model constructed is presented in Figure 1:

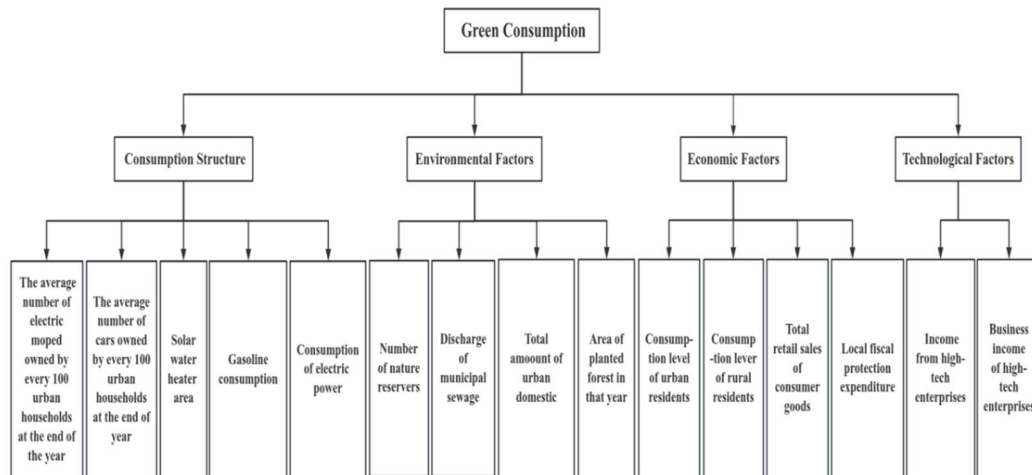


Figure 1 Analytic Hierarchy Model

The AHP calculation basis is a judgment matrix, in which people's cognition of the relative importance of each factor is reflected by the values of elements, thus affecting the decision-making effect. Usually, the elements of the judgment matrix are scaled from 1 to 9 and their reciprocal.

3.2.2 Judgment Matrix Construction

Table 2 Judgment Matrix and Its Scale Meaning

Scale	Meaning
1	Indicates that the two factors are equally important
3	Indicates that one is slightly more important than the other compared with two factors
5	Indicates that one is strongly important than the other compared with two factors
7	Indicates that one is significantly more important than the other compared with two factors
9	Represents the median value of the two adjacent judgments
2, 4, 6, 8	Indicates that one of two factors is extremely important than the other
Reciprocal	Assuming the comparison of the factors i and j achieves the judgment B_{ij} , the judgment of comparing the factors j and i is $B_{ji} = 1/B_{ij}$

3.2.3 Hierarchical Single Sorting and Consistency Test

Single sorting is the order of importance of each factor in this layer to a factor in the upper layer. It is represented by the eigenvectors of the judgment matrix. For example, the solution vector W of the characteristic problem $AW = \lambda_{\max}W$ of the judgment matrix A is the sorting weight of

the relative importance of the corresponding factors in the same level to a factor in the previous level after normalization. This process is called hierarchical single sorting.

Consistency index ($\lambda_{\max}$ is the largest eigenvalue of A)

$$CI = \frac{\lambda_{\max} - n}{n - 1} \quad (1)$$

Table 3 Random Consistency Index

Judgment Matrix Order n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Consistency ratio:

$$CR = \frac{CI}{RI} = \frac{\lambda_{\max} - n}{RI \cdot (n - 1)} \quad (2)$$

Only when $CR < 0.1$ will the result of hierarchical single sorting be satisfactory, otherwise the judgment matrix elements need adjustment.

3.2.4 Hierarchical Total Sorting and Consistency Test

The combined consistency ratio of the p -th layer to the first layer is:

$$CR^{(p)} = CR^{(p-1)} + \frac{CI^{(p)}}{RI^{(p)}}, p = 3, 4, \dots, s \quad (3)$$

Only when $CR < 0.1$ will the hierarchical total sorting results be considered to have satisfactory consistency. If $CR \geq 0.1$, the element values of the judgment matrix need to be readjusted.

Since $CR = 0.0574007 < 0.1$, the decision result is credible, with the AHP completed.

3.3 Indicator Weight Table

After constructing the last round of the AHP, the weight score table of the three-level indicators is in Table 4:

Table 4 Indicator Weight Table

First-Level Indicators	Second-Level Indicators	Third-Level Indicators	Third-Level Indicators Weights
Overall Development of Green Consumption	Consumption Structure	Average number of electric mopeds owned by every 100 urban household at the end of the year	0.0823
		Average number of cars owned by every 100 urban households at the end of the year	0.0426
		Solar water heater area	0.0199
		Gasoline consumption	0.0731
		Consumption of electric power	0.0823
	Environmental Factors	Number of nature reserves	0.0124
		Discharge of municipal sewage	0.0489
		Total amount of urban domestic water	0.0489
		Area of planted forest in that year	0.0215
		Consumption of urban residents	0.1152
	Economic Factors	Consumption of rural residents	0.1152
		Total retail sales of consumer goods	0.0338
		Local fiscal protection expenditure	0.1309
		Number of high-tech enterprises	0.0433
		Business income of high-tech enterprises	0.1300
	Technological Factors		

4. Fuzzy Comprehensive Evaluation

Fuzzy comprehensive evaluation based on fuzzy mathematics transforms qualitative evaluation into quantitative evaluation. It is used for multi-domain decision-making, determining evaluation factor set, comment set and weight set, and obtaining comprehensive evaluation by single-factor evaluation and fuzzy operation.

4.1 Factor Domain Determination of the Evaluation Object

$$U = \{u_1, u_2, \dots, u_k\} \quad (4)$$

There are k evaluation indicators, which indicate from which aspects the evaluated object can be judged and described.

4.2 Domain Determination of Comment

The comment set is composed of all the total evaluation results that the evaluator may give for the evaluated object, which is represented by V :

$$V = \{v_1, v_2, \dots, v_m\} \quad (5)$$

In fact, it divides the change interval of the evaluated object. V_i is the i -th evaluation result, and m is the total number of evaluation results.

4.3 Conduction of Single-Factor Evaluation and Fuzzy Relationship Matrix R

The evaluation from one factor alone to determine the membership degree of the evaluation object to the evaluation set V is called single-factor fuzzy evaluation.

For positive indicators:

$$\frac{X_{\min}}{X} \quad (6)$$

For negative indicators:

$$\frac{x}{x_{\max}} \quad (7)$$

Single-factor fuzzy evaluation is the evaluation from a single factor to determine the membership degree of the evaluation object to the evaluation set V . After

constructing the hierarchical fuzzy subset, the quantification is implemented for each factor u_i ($i=1, 2, \dots, m$) of the evaluated object in turn. Specifically, it requires to clarify the membership of the evaluated object to each level of a fuzzy subset from the level of a single factor. Through such an operation, the fuzzy relationship matrix can be obtained:

$$R = \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} \quad (8)$$

4.4 Fuzzy Weight Vector Determination of Evaluation Factors

To respond to the importance of each factor, a_i ($i=1, 2, \dots, m$) as a corresponding weight is assigned to each factor U , which is usually required to satisfy $a_i \geq 0$. $\sum a_i = 1$ is the

weight of the i -th factor, and a fuzzy set A consisting of each weight is the weight set.

4.5 Multi-Factor Fuzzy Evaluation

The model of a fuzzy comprehensive evaluation is as follows:

$$B = A \circ R = (a_1, a_2, \dots, a_m) \begin{pmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix} = (b_1, b_2, \dots, b_n) \quad (9)$$

Where b_j ($j=1, 2, \dots, n$) is obtained by the j -th column operation of A and R , which indicates the membership degree of the rated object to the fuzzy subset of V_j grade as a whole.

4.6 Output Results

Table 5 indicates the green economy development of each region.

Table 5 Development of Green Consumption in Various Regions

Provinces	Shanghai	Jiangsu Province	Anhui Province	Zhejiang Province	Hubei Province	Hunan Province
Score	0.6210	0.6966	0.5380	0.6023	0.5342	0.4642

5. Conclusion

(1) This study shows that green consumption in Jiangsu Province scoring 0.6966 ranks first.

There are different reasons why Jiangsu Province ranks first. In terms of policy, the government attaches great importance to sewage treatment and the establishment of nature reserves. Besides, its local environmental protection fiscal expenditure ranked first in 2022. In terms of enterprises, the number and revenue of high-tech enterprises are both high with prosperous development of high-tech enterprises, driving the green industry to thrive. In terms of consumption, residents' consumption is leading and they mostly adopt a green lifestyle, which has a social consensus on green consumption. The development of Jiangsu Province can provide valuable references and development experience for other regions.

(2) The green consumption of Shanghai scoring 0.6210 ranks second, and that of Zhejiang Province scoring 0.6023 ranks third.

Shanghai and Zhejiang Province have invested more in policy support and resource guidance in environmental protection and exploration of green consumption patterns, promoting the widespread dissemination and practice of green consumption concepts among the people. The two provinces have made small achievements in high-tech industries. Through continuous investment in scientific research and cultivation of innovative talents, a large number of high-tech achievements with core competitiveness have emerged, which not only boost the

transformation and upgrading of regional economic structure, but also provide technical support and industrial carrier for green consumption. In terms of consumption, residents' consumption is high and they use more clean energy. Their sewage discharge is also relatively small. Although there is an unbalanced regional development in the two provinces, such as the urban-rural consumption gap, with the urban consumption about 1.6 times that of rural areas. The high overall residents' consumption paves a way for the development of green consumption.

(3) The green consumption of Anhui Province ranks fourth, with a score of 0.5380. The green consumption of Hubei Province ranks fifth, with a score of 0.5342.

The green consumption scores of these two provinces are close. When it comes to the number of nature reserves, the two provinces occupy the first and second dominant positions respectively among the six provinces investigated. What stands out about Anhui Province is that its residents are very concerned about green travel and have a high number of electric vehicles, which reduces carbon emissions and energy consumption. It also shows that the residents in Anhui province have high green consumption literacy. However, the two provinces have some shortcomings. First of all, the overall consumption of residents is relatively low, which limits the market demand scale of related products and services to a certain extent. Meanwhile, the governmental fiscal expenditure on environmental protection is relatively low compared with other provinces.

(4) The green consumption of Hunan Province scoring 0.4642 ranks sixth.

The performance of green consumption in Hunan Province among the six provinces is poor. From the economic perspective, the consumption of residents is relatively low. Meanwhile, the governmental expenditure on environmental protection is the least compared with other provinces, which may trigger financial problems when carrying out environmental protection infrastructure construction, technology R&D, and ecological restoration. Furthermore, the low business income of high-tech industries in Hunan province indicates that the sales volume of high-tech products is lower than that of other provinces. It is difficult to drive the R&D of new technologies and the production of green products in a virtuous circle, which harms the long-term development of green consumption.

6. Suggestions

6.1 Raise Residents' Awareness and Practice Green Concepts

The improvement of personal awareness of environmental protection and the practice of green concepts are the basis for improving green consumption in the middle and lower reaches of the Yangtze River. First of all, the publicity of environmental protection and green products should be strengthened with all-round and multi-angle publicity through schools, communities and media, so as to enhance residents' attention to environmental protection and green products, thus stimulating their consumption. Secondly, people should be encouraged to adopt a green lifestyle, advocate green travel, and reduce the use of private cars. Besides, it's crucial to encourage new energy vehicles and eliminate gasoline vehicles, thus reducing carbon emissions and energy consumption. Finally, residents should be guided to start with the little things, such as saving water and electricity, sorting garbage and recycling resources, and reducing the use of disposable products.

6.2 Enterprises Innovate Production and Supply Green Products

Enterprises make a difference in the development of green consumption in the middle and lower reaches of the Yangtze River, which requires high-tech to produce green products. In this study, it is confirmed that technical factors are important factors affecting the development of green consumption. Thus, enterprises should increase investment in the R&D of green products, cooperate with scientific research institutions and universities, increase green production methods, and enhance green production technologies, such as efficient sewage treatment technology and resource reuse technology, so as to reduce pollutant emissions and resource waste in the production. In addition to using new technologies during production, it is necessary to follow the concept of green design in product design and manufacturing, give priority to environmentally friendly raw materials, improve the degradability, recyclability and energy efficiency of products, and develop green products, such as energy-

saving home appliances, green building materials, degradable packaging materials, etc., so as to meet the market demand for green products. Finally, enterprises need to report on the contribution of green product R&D, production and environmental protection to ensure that R&D and production activities meet the requirements of environmental protection standards and regulations.

6.3 Government Improves Policies and Guides Green Consumption

The government plays an irreplaceable leading and regulating role in improving green consumption. Firstly, the government should improve pertinent laws and regulations, clarify the standards of R&D and production of green products, promote the supervision mechanism of the green consumption market, ensure that consumers can choose qualified green products, and create a fair competition, standardized and orderly green consumption market environment. Secondly, through fiscal and taxation policies, enterprises should be guided to produce more green products, such as giving tax incentives and financial subsidies to enterprises that produce green products, so as to reduce production costs and improve the competitive advantage of green products. The government should encourage consumers to purchase green products through subsidies and preferential treatments, such as new energy vehicle purchase subsidies, green home appliance energy-saving subsidies, etc. In addition, the government should strengthen the procurement of green products, give priority to green products and services in government procurement activities, fully play the demonstration and leading role of government procurement, and promote the formation of social green consumption trends.

6.4 Promote Cooperation Among Provinces and Coordinated Regional Development

The six provinces in the middle and lower reaches of the Yangtze River should break geographical restrictions and strengthen regional cooperation. Based on the above research, each province has its advantages and disadvantages, and cooperation can make up for the shortcomings faster and promote regional green consumption. First of all, unified green consumption incentive policies should be regularly discussed and formulated, such as unified green product subsidy standards, so as to avoid market chaos and corporate arbitrage caused by inter-provincial policy differences. For green enterprises operating across regions, policy support such as sharing tax incentives and simplifying administrative approval processes will be provided to promote enterprises to extensively deploy green industries in the region. Secondly, all provinces should jointly fund the planning and construction of regional green consumption infrastructure. For example, we will jointly build a green transportation system in the Yangtze River Delta in transportation, unify standards for new energy vehicle charging facilities and build stations to ensure the convenient passage of electric vehicles in the region. In environmental protection facilities, it is necessary to cooperate in the construction of cross-regional garbage

classification and resource recovery centers to improve resource recycling efficiency and reduce garbage disposal costs. Finally, a regional green consumption information platform should be built to integrate green product information and consumption data of various provinces, etc., so as to provide a basis for precise marketing of enterprises and scientific choice of consumers.

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