Evaluation of Regional Heat Index for Recycling and Utilization of New Energy Vehicle Power Batteries Based on Regression Analysis

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Abstract: With the rapid development of China's new energy vehicle industry, power batteries will enter the retired and recycling stage after a period of on-board use. Therefore, the recycling and utilization industry of power batteries is gradually emerging and attracting increasing attention. The development level of the power battery recycling and utilization industry varies in different regions of China, influenced by factors such as policy environment and geographical conditions. Based on multidimensional data and regression analysis algorithm, this paper constructs a regional heat index for the recycling and utilization of power batteries in new energy vehicles, in order to provide a basis for government authorities and relevant industry enterprises for future investment layout and planning.

Keywords: New Energy Vehicles; Power Batteries; Recycling and Utilization; Heat Index

1. Introduction

In recent years, China's new energy vehicle industry has experienced rapid development, and the recycling and utilization industry of power batteries has been on the rise, attracting significant attention from various sectors of society. Government authorities have emphasized the importance of power battery recycling and utilization, urging swift construction of a comprehensive recycling and utilization system for power batteries. Concurrently, as power batteries in China gradually enter the stage of large-scale retirement, the market demand for recycling and utilization continues to rise, leading to increased willingness among upstream and downstream companies in the industry chain as well as social capital to invest in this area. Focusing on the recycling and utilization industry of power batteries, the aim is to comprehensively, intuitively, and objectively display the devetablelopment status, regional characteristics, and differences in China's power battery recycling and utilization industry through the form of an index. This index analyzes multiple dimensions such as attention to industries, development scale and quality, and retirement and recycling potential, with the goal of scientifically assessing the development level of power battery recycling and utilization in different regions. It provides a strong reference for government authorities in planning local industrial development and guiding corporate investment strategies, thus empowering the sustainable development of the power battery industry.

2. Index Evaluation System

The regional heat index for recycling and utilization is established based on five primary indicators: attention to industries, scale and quality of industrial development, retirement battery recycling potential, industry policies and development environment, and industry innovation status. Additionally, there are 17 secondary indicator [1, 2]. In consideration of the characteristics of comprehensive utilization industries, three-level indicators are set for cascade utilization and recycling, as shown in Table 1.

The evaluation indicators for the regional heat indexes for recycling and utilization were sourced from the National Traceability Platform, public information from the Ministry of Industry and Information Technology, local governments, local energy bureaus, and the power system, as well as industry databases. The data underwent dimensionless processing through the use of range normalization. The

weights of the indicators for the cascade utilization and recycling thermal indexes were determined using the plate regression analysis method, as shown in Fig. 1. The weights are calculated as follows:

$$\ln Y_i = \ln A_0 + \sum_{i=1}^{17} \alpha_i \ln X_i + \omega_i + \varepsilon_i \qquad (1)$$

Where, Y represents the dependent variable, which directly measures the value of the comprehensive utilization thermal index (regional waste battery processing quantity).

A_0 is a constant used to adjust for the parameters in the independent variables that were not included in the statistics but still affect the dependent variable. α denotes the parameter for each second-level indicator, reflecting the quantitative change of the dependent variable with respect to the independent variables. X_i represents the indicators of all independent variables, and $\omega_i + \varepsilon_i$ is the error term, used to measure the unaccounted errors not included in the statistics.

Table 1. Three-level Indicators for Cascade Utilization and Recycling

| S/N	First-level indicators	Second-level indicators	Remarks
1	Attention to regional industries	National Platform Registration Status	Differentiating between cascade utilization and recycling.
2		Registered Enterprise Activity Level	
3		Recycling Channel Development	Status of service points and their joint construction, certification points, and regional central stations.
4	Scale and quality of regional industrial development	Number of Enterprises in the Comprehensive Utilization White List	Differentiating between cascade utilization and recycling.
5		Production Capacity of Enterprises in the Comprehensive Utilization White List	
6		Activity Level of Enterprises in the Comprehensive Utilization White List	
7		Establishment of Industry Alliances	
8	Regional Potential for Retired Battery Recycling	Forecast of Power Battery Recycling Volume	Recycling projections for the next five years.
9	Regional Industry Policies and Development Environment	Environmental Restriction Policies	Indicators for recycling.
10		Introduction of Recycling-Related Policies	
11		Development of Related Industries	Number of battery companies and their production capacity, as well as the number of registered automotive dismantling companies.
12		Installed Photovoltaic Capacity	Indicators for cascade utilization.
13		Installed Wind Power Capacity	
14		Electricity Cost	Indicators for recycling.
15	Regional Industry Innovation Status	Special Support	
16		Technological Breakthroughs	Status of patent publications.
17		Formulation of Standards	Involvement of local enterprises in national, regional, and industry standards research.
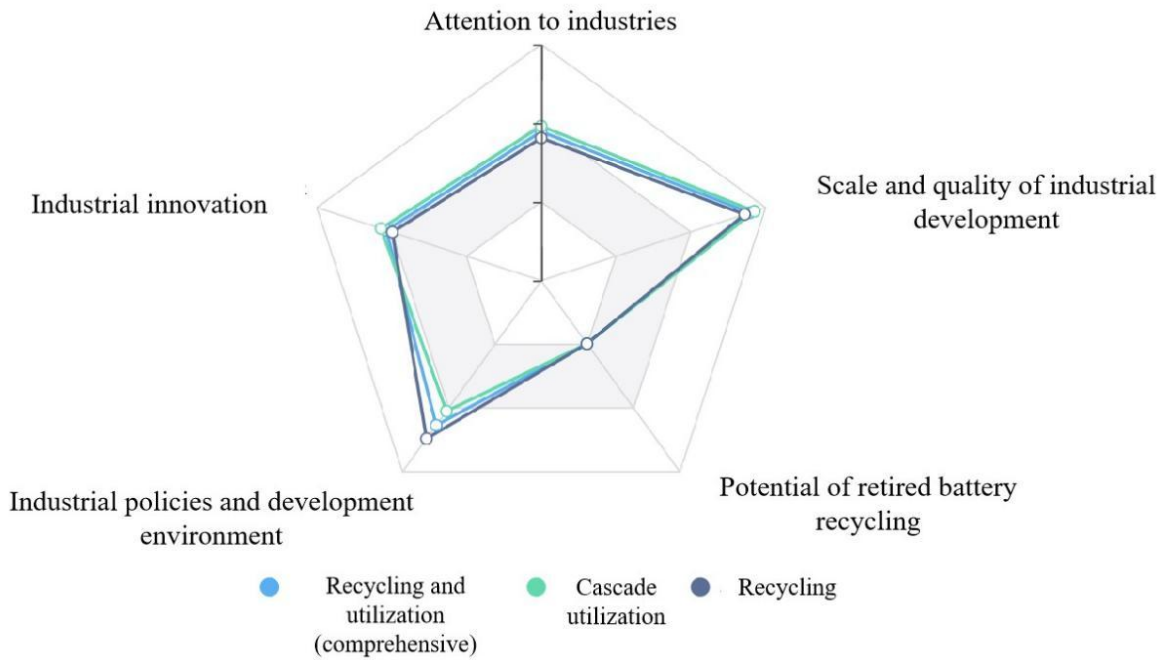
Fig 1. The Weightings of the Indicators Influencing the Heat Indexes for Recycling and Utilization

3. Analysis of Indicator Factors

Attention to regional industries: This key indicator measures the heat and attention of industrial layout from a market perspective. It evaluates the indicator factors separately for the recycling and comprehensive utilization stages, encompassing indicators such as the development of recycling channels, the layout of comprehensive utilization enterprises, and the level of enterprise activity [3,4]. As shown in Fig. 2, provinces such as Guangdong, Zhejiang, Jiangsu, Shandong, and Hebei exhibit higher levels of industrial attention.
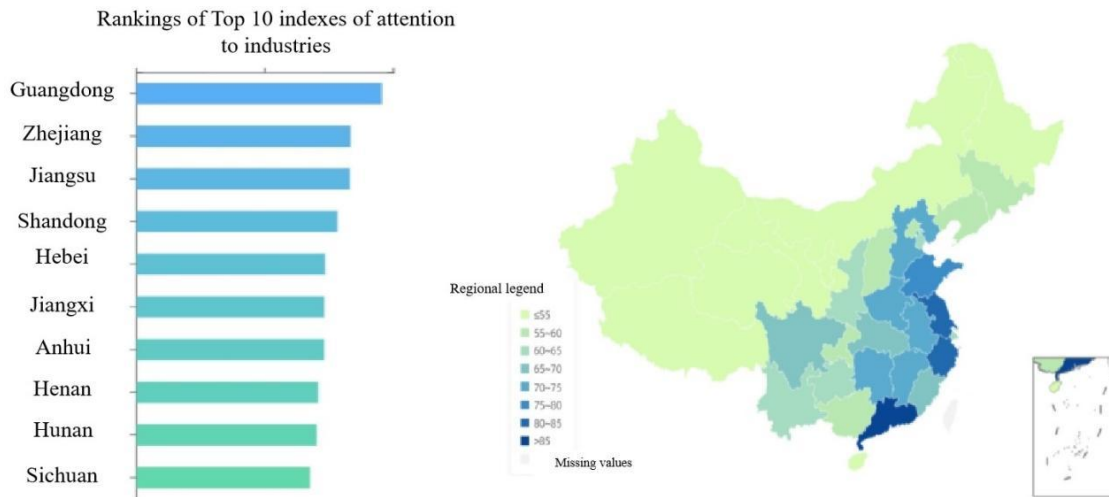

Fig 2. The Heatmap of the Attention to Regional Industries

Scale and Quality of Regional Industrial Development: This is one of the important indicators that measure the quality of regional development in the recycling and utilization industry. This indicator focuses on evaluating the layout of high-quality enterprises and the coordinated development of the industry. It encompasses indicators such as the number of standardized enterprises, production capacity, enterprise activity, and the formation of industry alliances. As shown in Fig. 3, provinces and cities such as Jiangxi, Hunan, Guangdong, Zhejiang, and Jiangsu rank higher in the evaluation of industrial development scale and quality.
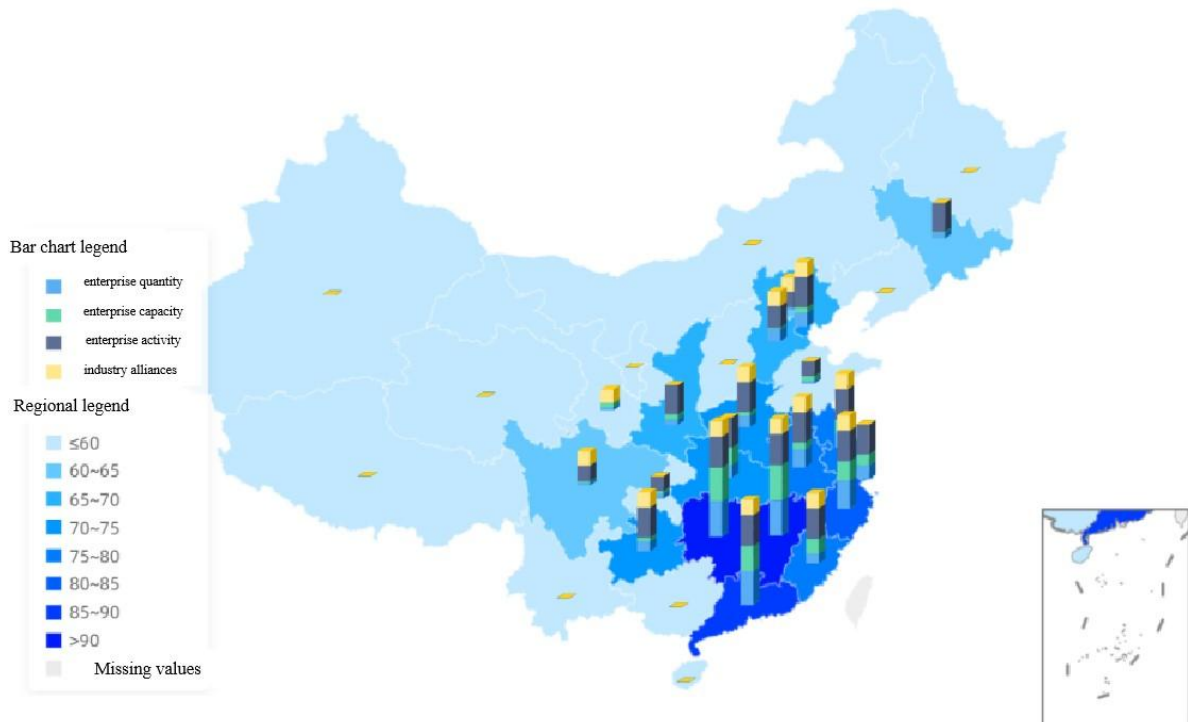
Fig 3. The Heatmap of the Scale and Quality of Regional Industrial Development

Regional Potential for Retired Battery Recycling: This is an important indicator that measures the foundation of regional recycling industry development [5]. This indicator examines the forecasted number of retired power batteries in the next five years and evaluates the potential volume of recoverable batteries in the region. As shown in Fig. 4, Guangdong, Zhejiang, Jiangsu, Shanghai, Beijing, and other provinces and cities rank high in terms of the potential for retired battery recycling, with Guangdong possessing a significant advantage over other provinces and cities.
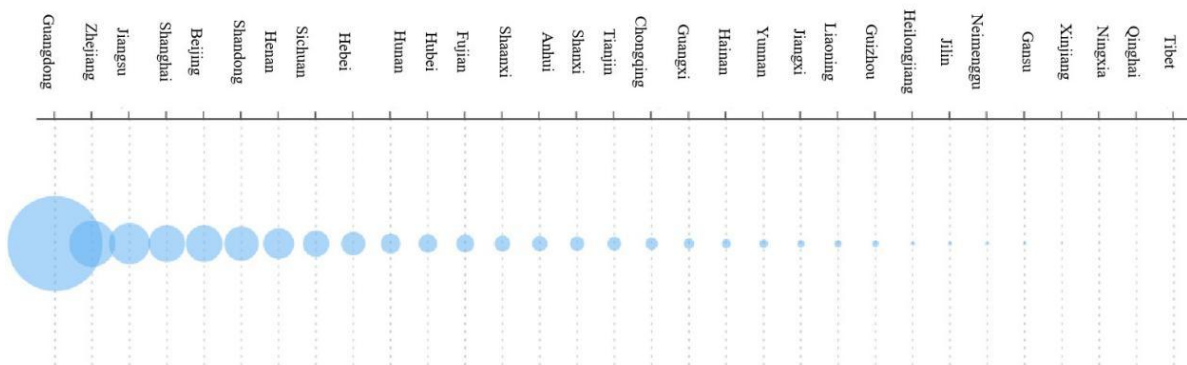

Fig. 4 The Distribution Map of Regional Potential for Retired Battery Recycling

Regional Industrial Policies and Development Environment: This is an important indicator that measures the foundation of regional recycling industry development [6-8]. This indicator examines the implementation of recycling industry policies and the restrictions imposed by environmental policies, as well as the development of related industries such as battery production and scrapped vehicle dismantling, and factors like energy costs and market opportunities. As depicted in Fig. 5, Yunnan, Shandong, Chongqing, Fujian, Ningxia, and other provinces and cities rank high in terms of the Industrial Policies and Development Environment Index.
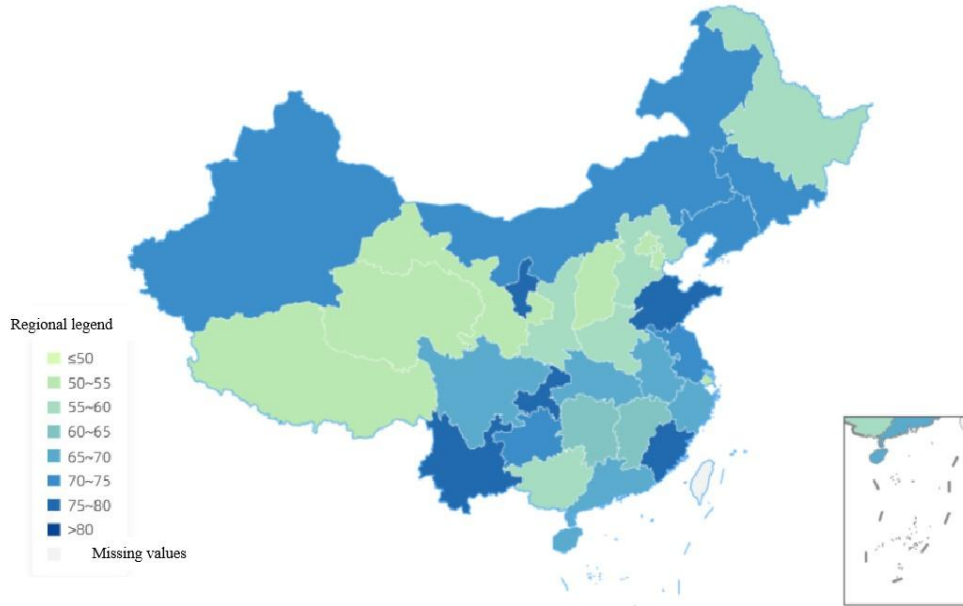
Fig 5. The Heatmap of the Regional Industrial Policies and Development Environment

Regional Industrial Innovation Status: This is an important indicator that measures the foundation of regional industries and the technological strength of enterprises [9,10]. This indicator assesses the support for recycling and utilization industries, patent releases, and participation in standard research. As depicted in Fig. 6, Guangdong, Hunan, Anhui, Zhejiang, Jiangsu, and other provinces exhibit notable strengths in industrial innovation.
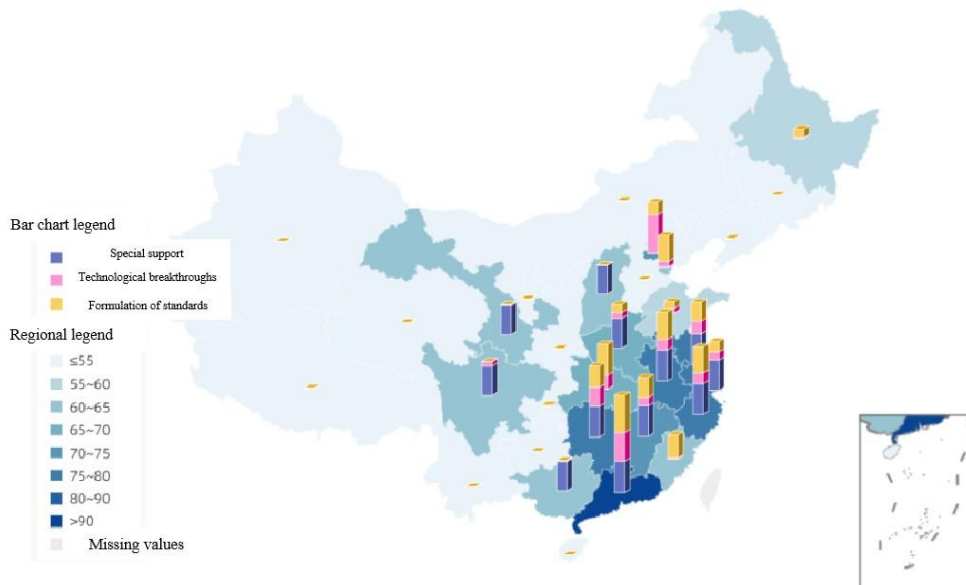

Fig 6. The Heatmap of the Regional Industrial Innovation

4. Conclusions from the Analysis of Heat Index in Various dimensions

4.1 Heat Index for Recycling and Utilization

There are significant differences in the level of industrial development across the country. As shown in Fig. 7, Guangdong province stands out with an absolute advantage in terms of attention to industries, recycling potential, and industrial innovation. Additionally, Zhejiang, Jiangsu, Hunan, Jiangxi, and Anhui belong to the second tier. The concentration effect of the dynamic battery recycling and utilization industry in the East China region is prominent, positioning the industry at the forefront of national development. Furthermore, factors such as the characteristics of the

comprehensive recycling and utilization industry and regional environmental restrictions policies impact the evaluation of the recycling and utilization industry's development in top-tier cities like Beijing and Shanghai.
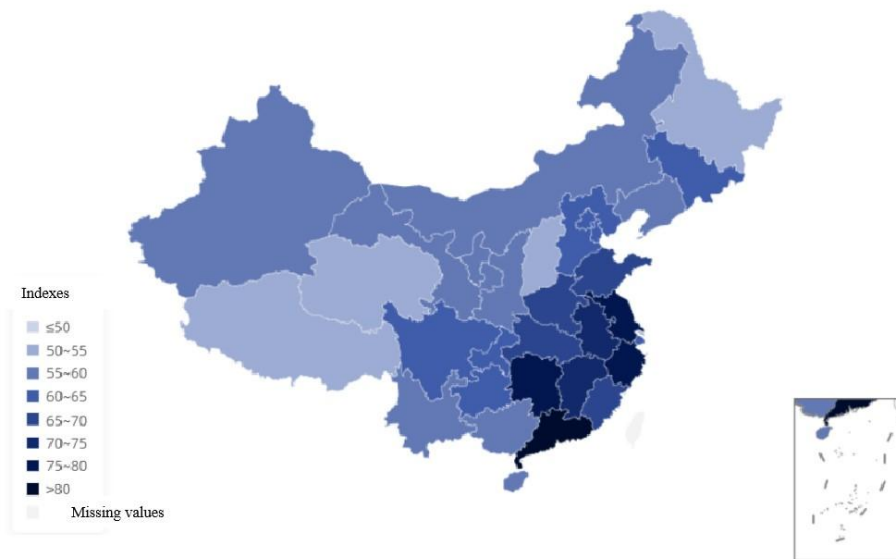

Fig 7. The Heatmap of the Industrial Development Index of the Recycling and Utilization

In terms of regional development levels, there are notable differences across different regions. As depicted in Fig. 8, the recycling and utilization industry in Eastern China, including provinces like Jiangsu, Zhejiang, Jiangxi, and Anhui, exhibits a relatively balanced level of development, with a prominent regional industry clustering effect. The Central-South region is influenced by the development of the recycling and utilization industry in Guangdong and Hunan and Hubei, gaining high evaluations in terms of industrial scale, quality, recycling potential, and innovation. In the Southwest region, provinces such as Sichuan, Guizhou, and Chongqing experience significant development potential in the recycling and utilization industry due to industrial policies and the development environment, which further contribute to the rapid growth of industries in the Southwest. In the North China region, the Beijing-Tianjin-Hebei area is greatly impacted by environmental protection policies, but possesses certain advantages in terms of industrial innovation.
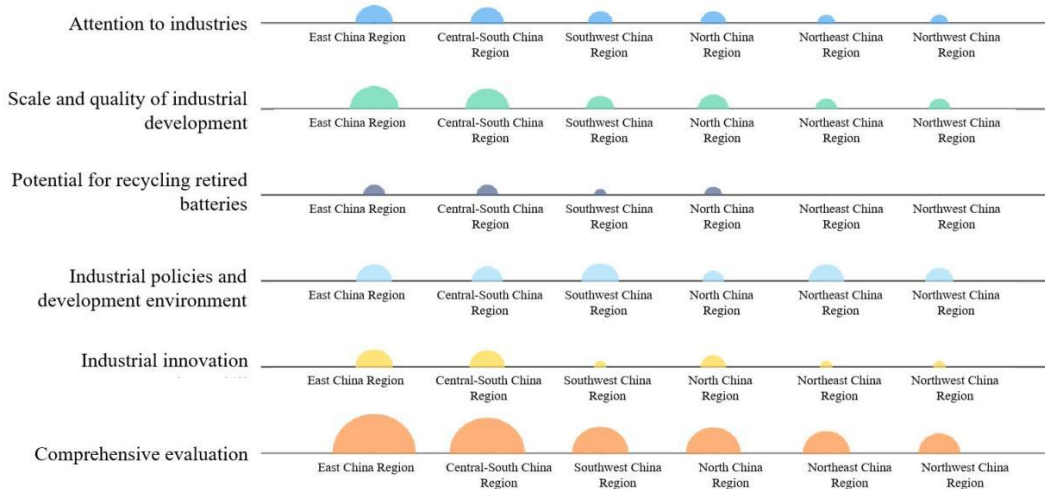

Fig 8. The Comparative Graph of the Regional Industrial Development of the Recycling and Utilization

4.2 Evaluation of the Cascade Utilization Heat Index

Guangdong province demonstrates outstanding performance across various indicators, exhibiting significant advantages over other provinces and cities, as illustrated in Fig. 9. Jiangsu, Zhejiang, Hunan, and Jiangxi closely follow behind. Among them, Jiangsu and Zhejiang provinces display a balanced performance across all evaluation indicators, showcasing rapid industrial development. Hunan, Jiangxi, and Anhui provinces possess certain advantages in terms of industrial scale, quality, and innovation, indicating considerable development potential and market space.
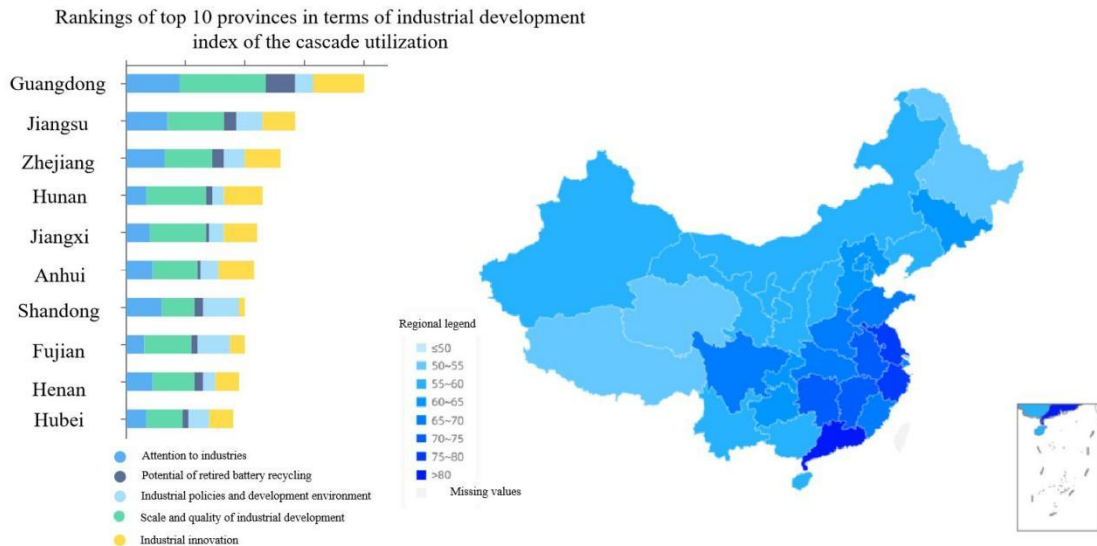

Fig 9. The Heatmap of the Industrial Development of the Cascade Utilization

4.3 Evaluation of the Recycling Heat Index

Guangdong, Zhejiang, Hunan, Jiangxi, and Jiangsu provinces rank higher, as shown in Fig. 10. Among them, Guangdong province receives high evaluations across various dimensional indicators, highlighting its significant advantages in industrial development. Zhejiang, Hunan, and Jiangxi demonstrate clear advantages in terms of industrial scale and quality. Jiangsu, Anhui, Fujian, and Hubei provinces possess a solid industrial foundation and favorable policy environment, indicating substantial future development potential.
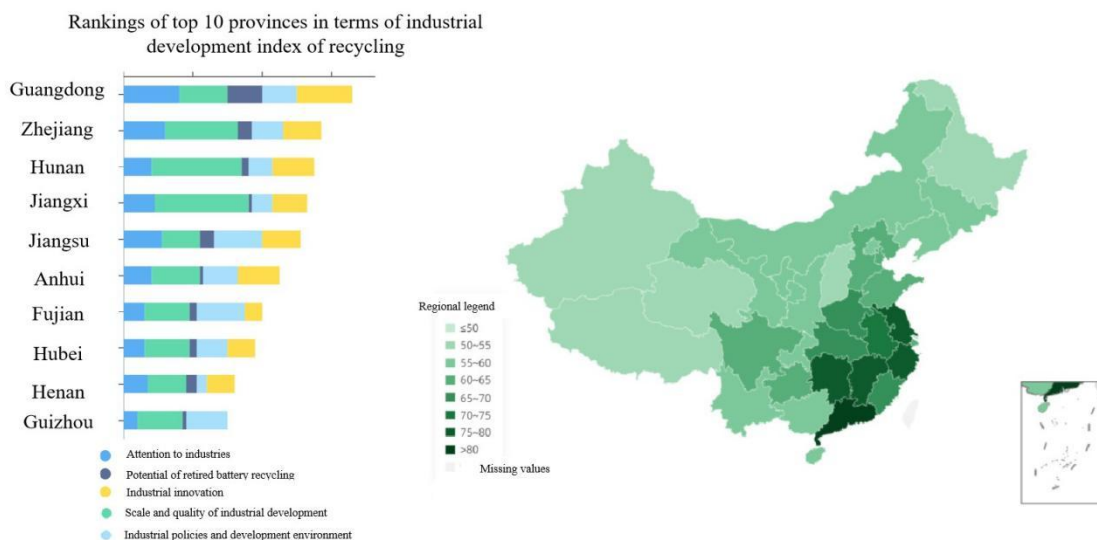

Fig 10. The Heatmap of the Industrial Development of Recycling

Based on the analysis of different dimensions such as industrial innovation, attention to industries, scale and quality of industrial development, industry policies and development environment, and recycling potential, the data indicates that Guangdong, Zhejiang, Jiangsu, and Hunan exhibit strong overall capabilities in the development of the dynamic battery recycling industry. Therefore, these regions can be prioritized for investment and strategic planning.

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