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RESEARCH OF THE PEARL RIVER DELTA URBAN AGGLOMERATION POWER BATTERY INDUSTRY BASED ON SCP PARADIGM

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Abstract : Power battery is a hot field in the current new energy industry, and China is developing rapidly in the power battery industry. The power battery industry in The Pearl River Delta urban agglomeration (Short form "PRD") is highly representative in the world. This paper combines the structure-Conduct-performance (Short form "SCP ") Paradigm in industrial organization theory with the upstream, midstream and downstream of the power battery industry. The detailed analysis of each link of the PRD power battery industry from the regional and industrial perspectives confirms that the current PRD power battery industry has initially formed a complete industrial chain and has strong competitiveness in the global scope.Three problems were found in the industrial link, and four suggestions were put forward, including improving the industrial layout, strengthening scientific research support, increasing policy strength, and further opening up and cooperation. Theoretically, this study enriches the application of SCP Paradigm and fills the literature gap of PRD power battery industry research. In reality, the experience of PRD power battery industry development can provide reference and enlightenment for the development of new energy industry in other regions of the world.

Keywords **- SCP paradigm,PRD urban agglomeration,Power Battery Industry.**

CHAPTER 1
INTRODUCTION

1.1 General

The new energy vehicle industry has the competitive advantage of low-carbon and environmental protection, and has become a new hot spot in the development of global low-carbon economy. As the core component of new energy vehicles, power battery industry has also entered a stage of rapid development. The global power battery market will be $64.7 billion in 2022, up 85.4%.

The mainstream power batteries in the market are divided into lead-acid batteries, nickel-metal hydride batteries, lithium batteries and fuel cells [1]. Battery specifications are complex, generally measured by the installed amount of battery (KWH). There are three stages from raw materials to terminal products of power batteries: the upstream is the selection and production of battery materials, the Midstream reaches are the manufacturing of battery cells and battery module assembly, and the downstream is the operation and utilization of power batteries, and recycling and decomposition.

1.2 Research Objectives

This paper hopes to conduct research on the power battery industry in representative regions by sorting out the development environment and development overview of the global power battery industry, carry out analysis on the situation of each link of the industry, and find industrial problems. Summarize the industrial development model and characteristics, and put forward suggestions.

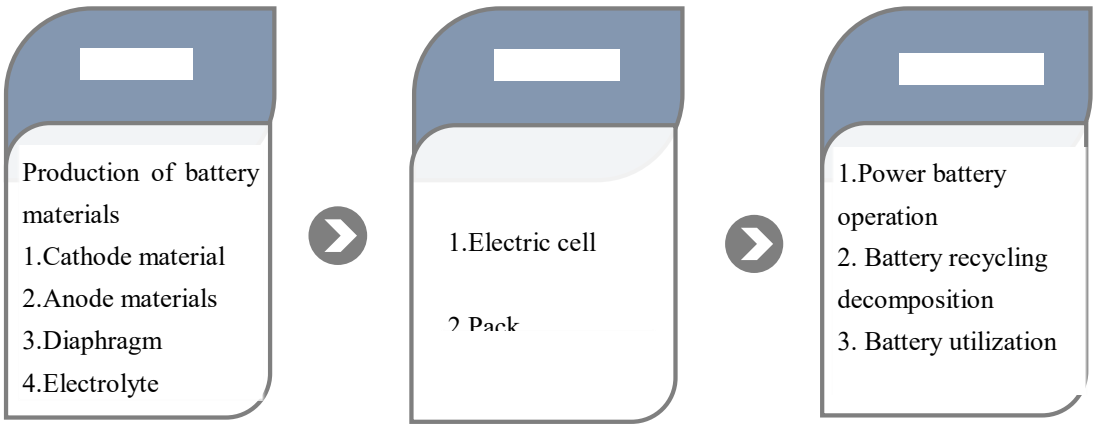


Figure 1-1：Power Battery Industry

Source: China Association of Automobile Manufacturers

1.3 Need of the study

Through this study, three problems can be solved: 1. Based on the structure-Conduct-performance (Short form "SCP ") Paradigm analysis framework of industrial organization theory, the research on the current situation of The Pearl River Delta urban agglomeration (Short form "PRD") power battery industry can enrich the application of SCP Paradigm and fill the gap in the existing case study of PRD power battery industry; 2. Help power battery industry and related enterprises to improve their competitiveness; 3. Summarize the development mode and characteristics of PRD power battery industry, and provide experience for the development of other regional industries.

CHAPTER 2

LITERATURE REVIEW AND RESEARCH METHODOLOGY

The methodology section outline the plan and method that how the study is conducted. This includes Universe of the study, sample of the study,Data and Sources of Data, analytical framework. The detailsare as follows;

2.1 Universe of the study

French geographer J.Gottman (1957) defined metropolitan area as the advanced spatial organization form of urban development to the mature stage . Through close contact, cities complement each other's advantages and generate maximum benefits.[2]

Figure 2-1：Schematic diagram of the Pearl River Delta urban agglomeration

At the end of 2008, The State Council of China issued the Outline of the Reform and Development Plan for the Pearl River Delta Region[3], which includes nine cities including Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing. The total GDP in 2022 will reach 1.52 trillion US dollars, accounting for 8.1% of China's total GDP. GDP per capita and GDP per land are more than one time of China's average level.

PRD power battery industry developed earlier than other regions, with a higher proportion, and has formed a relatively complete power battery industry cluster. The four key materials of power batteries and battery manufacturing occupy an important market position in China. In battery materials upstream of the industry, it has a number of enterprises in the forefront of their respective fields, such as German Nano, Beitrui, Tianci materials and Xingyuan materials. In the midstream battery manufacturing side of the industry, Build Your Dreams(BYD), sunwoda and Energy Very Endure(EVE) will enter China's TOP10 in 2022, with a total installed capacity of 84GWh. In the field of power battery recycling downstream of the industry,GME Green beauty, Brunp and other industry leaders have emerged. In terms of the regional distribution of enterprises, leading enterprises are mainly concentrated in Guangzhou, Shenzhen, Huizhou and other cities, and PRD is also distributed in other cities.

PRD is the economic center of southern China, with the strongest degree of openness, economic vitality, population agglomeration, innovation ability, and comprehensive strength. Therefore, it is representative and necessary to select the power battery industry in the Pearl River Delta for research.

2.2 Sample

The global power battery industry is mainly concentrated in China, Japan and South Korea, with CR3 accounting for 91% of the global output, represented by CATL, BYD, Panasonic, LG Chem, SK On and Samsung SDI. The scale of China's power battery industry has overtaken Japan and South Korea since 2015 to become the world's largest.

Table 2-2：Global usage of power battery equipped electric vehicles

Rank	Battery Supplier	2022 Unit：GWh	2021 Unit：GWh	Growth Rate	2022 Market Share	2021Market Share
1	CATL	191.6	99.5	92.5%	37.0%	33.0%
2	LG	70.4	59.4	18.5%	13.6%	19.7%
3	BYD	70.4	26.4	167.1%	13.6%	8.7%
4	Panasonic	38	36.3	4.6%	7.3%	12.0%
5	SK On	27.8	17.3	61.1%	5.4%	5.7%
6	Samsung SDI	24.3	14.5	68.5%	4.7%	4.8%
7	CALB	20	8	151.6%	3.9%	2.6%
8	Guoxuan	14.1	6.7	112.2%	2.7%	2.2%
9	sunwoda	9.2	2.6	253.2%	1.8%	0.9%
10	Farasis	7.4	2.4	215.1%	1.4%	0.8%
	Others	44.5	28.5	55.9%	8.6%	9.5%
	Total	517.9	301.5	71.8%	100%	100%

source: SNE Research

Among the world's TOP10 power battery companies in 2022, there are six Chinese companies. Among them, BYD and sunwoda are from PRD. The installed capacity of PRD power battery enterprises in 2022 accounts for 28.9% of China's total and 16.6% of the global share [3].

The Case analysis parties method is adopted to select the PRD power battery industry as the research object to carry out the case study. Through sorting, there are 43 enterprises in each link of PRD power battery industry involved in this study, including 28 in the upstream, 13 in the Midstream and 2 in the downstream. In order to avoid confusion with the new energy vehicle industry and make the analysis more focused, the mining and processing of upstream raw materials (lithium, cobalt, etc.) of power batteries and the production and sales of downstream new energy vehicles are excluded.

2.3 Data and Sources of Data

At the end of 2015, the 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) was held. In 2017, countries around the world gave their own fuel vehicle withdrawal schedule and electric vehicle promotion strategy. In the same year, a large number of sales of Tesla Model 3 meant that consumers began to accept electric vehicles.Therefore, the research time node of this paper mainly starts from 2017, which is the original year when electric vehicles and related industries begin to mature.

Through the Literature research method, a large number of documents related to the theory of industrial organization theory SCP paradigm and the power battery industry chain were consulted. We searched industry reports and annual reports of listed enterprises from the Ministry of Industry and Information Technology of China, China Securities Regulatory Commission, China Association of Automobile Manufacturers, China Automotive Power Battery Industry Innovation Alliance and other institutions. By sorting out the data and research conclusions in the literature, I systematically learned the theoretical tool "SCP paradigm of industrial organization theory" and the latest knowledge in the research field of power battery industry.

2.4 Theoretical framework

In this paper, The Structure-Conduct-Performance paradigm (SCP) of industrial organization theory is used as the theoretical framework, and a variety of research methods are comprehensively used to analyze the PRD power battery industry, so as to achieve the research goal.

In 1938, the Industrial organization of Harvard University studied the relationship among organizational structure, enterprise conduct and competitive Performance in market competition. Bain(1959) used industrial economic analysis methods to conduct empirical research and constructed a systematic framework for industrial organization analysis, referred to as SCP analysis framework [5]. Market Structure refers to the relationship between competition and monopoly among enterprises in the same industry, and also involves the relationship between sellers and buyers. Market Conduct refers to the measures taken by enterprises to obtain market share and economic profits. Market Performance, which points out that market structure and conduct will affect product price, production volume, profit, technology level and other market performance. This research paradigm has since become a powerful analytical tool for many industries.

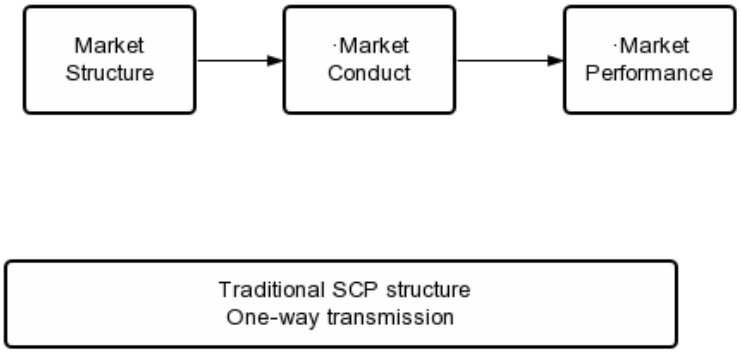


Figure 2-2

At present, the SCP paradigm is widely used in various fields of analysis, and is constantly modified and improved. Nobel Prize winner Jean Tirole(2001) made a detailed discussion on market power and institutional regulation [6]. The Japanese scholar Uecusa (2000) combined the theory of industrial organization with Japan's related industries and social systems [7]. Zhao Dan (2016) used SCP research framework to analyze the overall situation of China's cinema industry from four aspects: market characteristics, industry concentration, market barriers and industrial differentiation, and proposed a path to optimize the market structure of the cinema industry [8].

SCP paradigm analysis can point out the problems and contradictions existing in the industry, and provide targeted good suggestions. At present, there is not much involved in the research of power battery industry. In this paper, SCP analysis framework is used to discuss and study the related problems of power battery development, in order to promote the healthy development of power battery industry.

CHAPTER 3
ANALYSIS OF THE MODELS
Research on SCP Paradigm of PRD power battery industry

This section describes the use of SCP paradigm analysis model to study the market structure, market conduct and market performance of upstream, midstream and downstream enterprises in the PRD power battery industry.

3.1 Research on SCP Paradigm of PRD power battery industry upstream

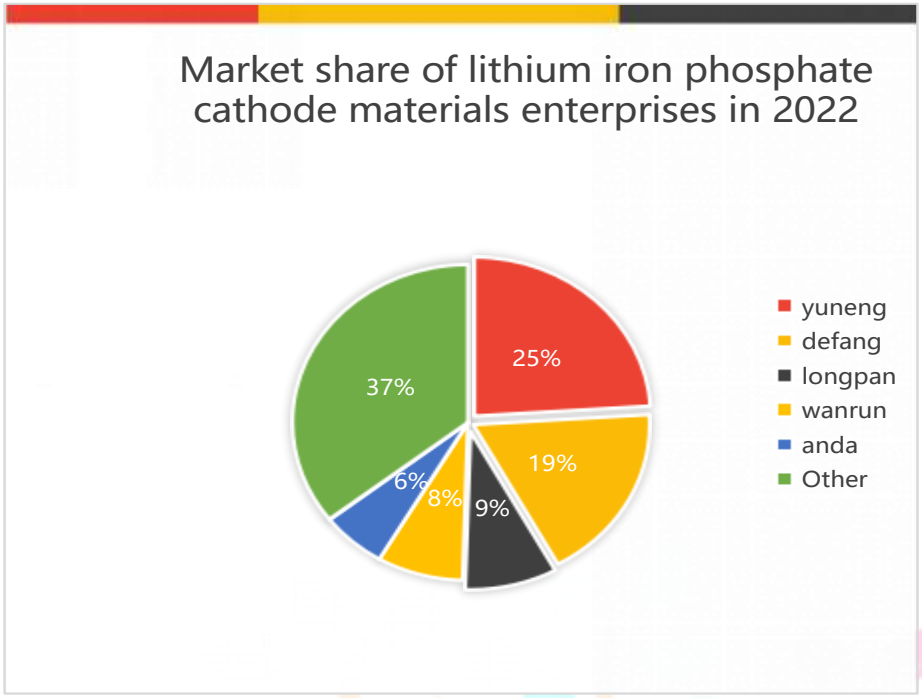
The upstream link of the power battery industry has four parts:Cathode material, Anode material, diaphragm and electrolyte.In this section, the SCP paradigm is used to study these four links.

3.1.1 Analysis on Market structure of PRD power battery industry upstream

The CR10 of the cathode materials market in 2022 will be 60%, with lithium iron phosphate enterprises accounting for 6 and ternary lithium enterprises accounting for 4. The concentration is lower than in the upstream area of other cells.In terms of market segments, the overall competition in the lithium iron phosphate cathode material market is fierce, and the market concentration has been reduced, with CR5 of 57% in 2022; The ternary lithium cathode material market is driven by a significant increase in exports, with CR5 rising 5% to 60.4% in 2022. With the maturity of the industry, the market concentration of Cathode materials will gradually rise.

In terms of product shipment structure, the highest market share of cathode materials is lithium iron phosphate and ternary lithium materials, accounting for 59% and 34% respectively. Among them, the market concentration of lithium iron phosphate cathode materials is high, CR5 is 76.5%. The corporate headquarters in PRD include German Nano, BYD and Beitrui, which shows that PRD has a great influence in iron lithium cathode materials. The market concentration of ternary lithium cathode materials is relatively low, CR5 is 61%, and no large-scale enterprises have emerged in PRD.

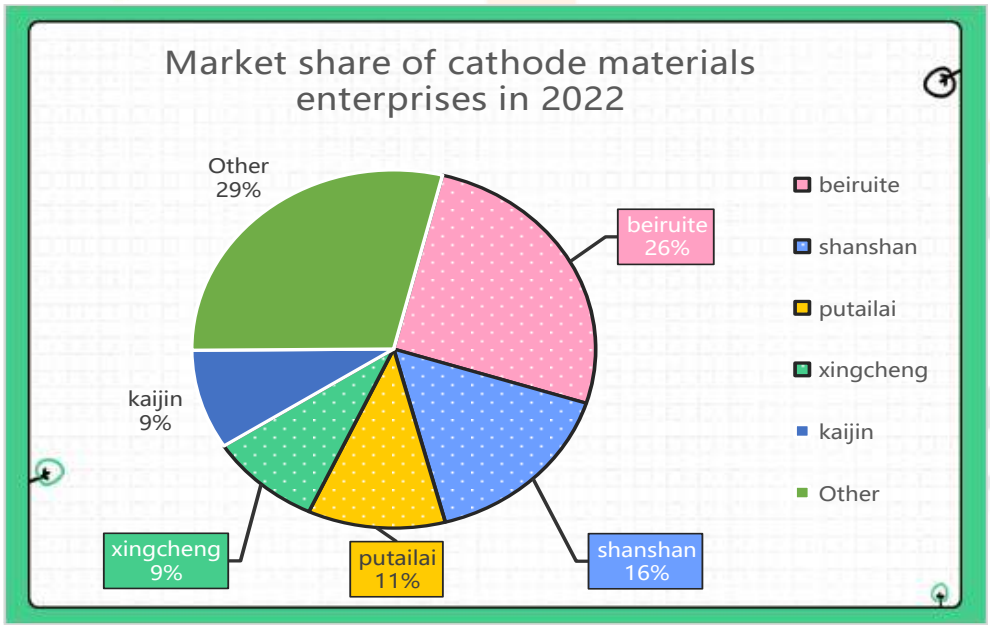
Table 3-1-1



source: Financial statements of listed companies

The market concentration of Anode material has decreased, the proportion of artificial graphite products has further increased, and PRD enterprises have strong competitiveness. The global shipments of negative materials market in 2022 increased by 71.9% compared with 2021, with China accounting for 90% of the global shipments of negative materials. China has a high concentration of Anode material market, CR3 is 51%. In terms of product structure of Anode material, artificial graphite market accounted for 84%. The competition pattern of leading enterprises in the Anode material market is relatively clear. In 2022, there are 4 PRD enterprises in the top10 negative electrode market, including Beitrui, Dongguan Kaijin, Xiangfenghua and Guangdong Dongdao, with obvious advantages.

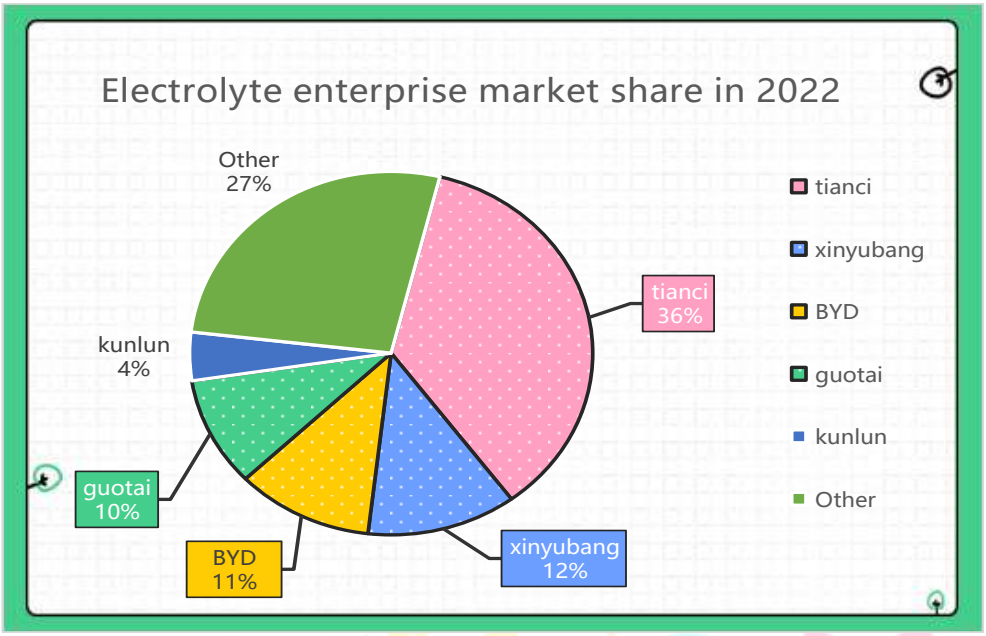
Table 3-1-2



source: Financial statements of listed companies

Driven by overseas demand, the leading enterprises grow rapidly, and the concentration of electrolyte market has been greatly improved. PRD enterprises are in a leading position. The global electrolyte market shipments grew by 70.4% YoY in 2022. China's shipments of electrolytes accounted for 85.4% of the world's total. The CR6 of China's electrolyte market is 77.6%, CR3 is 61.4%, PRD has Tianci Materials, Xinzhou Bang, BYD, Zhuhai Sywei and other four in China's top10 electrolyte shipments enterprises. PRD is highly competitive in the electrolyte industry.

Table 3-1-3



source: Financial statements of listed companies

The concentration of China's diaphragm market has increased significantly, and the number of PRD leading enterprises is small. China's diaphragm shipments accounted for 80% of global shipments in 2022. CR6 of China's diaphragm market is 75% and CR3 is 56%, down 2% from 2021, indicating a decrease in market concentration. Battery separator is divided into wet separator and dry separator, wet separator industry high technical barriers, high capital investment, long construction cycle. In terms of product structure, wet diaphragm shipments accounted for 78.7% of the total shipments in 2022, while dry diaphragm shipments accounted for 21.3%, up 4.1% from the previous year. PRD has no leading position in the wet diaphragm market. In the dry diaphragm industry, PRD has Xingyuan materials, Bosheng technology and Foshan Yingbolai and other 3 enterprises have a certain strength.

Table 3-1-4：Market share of major diaphragm enterprises

Segment market	Enterprise	Headquarters in China	Market share in 2022
Wet diaphragm	Enjie	western china	47%
	Zhongcai	eastern china	21%
	Xingyuan	PRD	11%
	Jinli	north china	9%
Dry diaphragm	Zhongke	central china	31%
	Xingyuan	PRD	26%
	Huiqiang	central china	24%
	Bosheng	PRD	11%

Source : Organized according to public data on the Internet

3.1.2 Analysis on market conduct of PRD power battery industry upstream

From the perspective of capital expenditure, the pace of investment and production expansion of positive material head enterprises has slowed down slightly, and PRD enterprises follow the trend and coordinate the layout with upstream and downstream enterprises. Ternary lithium material enterprises are accelerating the improvement of the upstream and downstream layout of the industrial chain, increasing investment in the upstream raw material link to improve control and enhance product competitiveness. Lithium iron phosphate material enterprises are increasing the construction of iron source capacity and integrating their own industrial chain to reduce costs.

Negative material enterprises focus on the layout of upstream, improve the ability to guarantee raw materials. With the gradual maturity of artificial graphite production technology, the quality of graphitization has become a key link to determine the quality stability of artificial graphite. In order to ensure product quality and supply chain stability, it has become an industry trend for major cathode material enterprises in China to lay out graphitization projects.

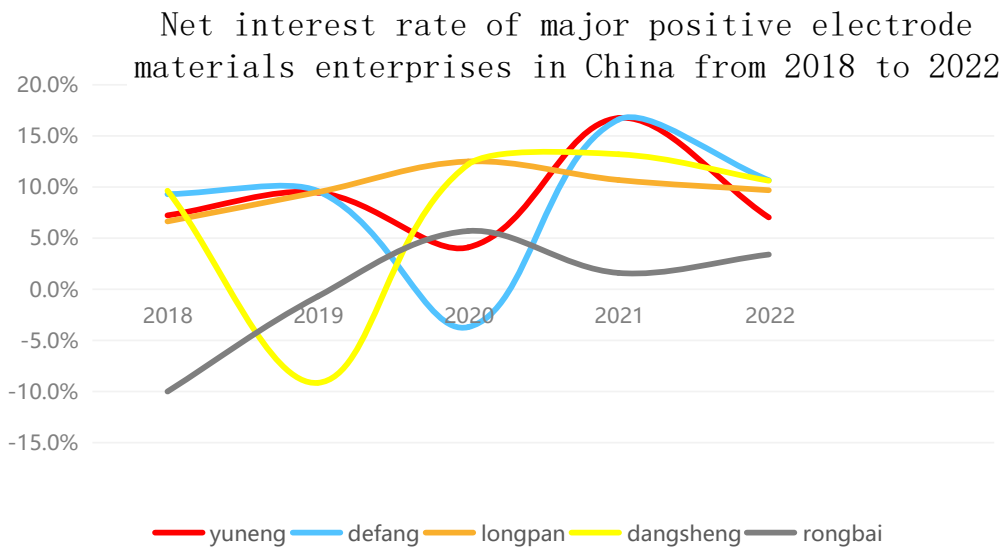
The investment expansion of leading enterprises in the diaphragm market fell from a high level, the expansion pace of PRD enterprises was stable, and the market integration continued to advance. In the past two years, the capital expenditure of diaphragm market has been at a high level, and the industry will have a large number of new capacity put into the market in the future. From the perspective of industry resource integration, capital integration is mainly horizontal integration, which will further compress the living space of second and third line wet diaphragm enterprises, and the diaphragm market will increasingly gather to leading enterprises in the future.

Electrolyte leading enterprises expand at a stable speed, PRD enterprises actively layout new additives. Two PRD electrolyte leading enterprises Tianci materials, new Zhou Bang continue to layout overseas, remote production capacity will be quickly released. On the other hand, enterprises focus on the vertical integration of the electrolyte industry, accelerating the layout to the upstream additives, solvents and new lithium salts.

3.1.3 Analysis on market performance of PRD power battery industry upstream

PRD lithium iron phosphate material enterprise net interest rate remains relatively stable, ternary lithium material enterprise profitability bottlows out. Since 2019, the price of lithium iron phosphate cathode materials has fluctuated seriously, and the profitability has begun to recover. In ternary lithium cathode materials, companies' net margins also declined in early 2019, before starting to rebound. Increased demand in 2023 increased capacity utilization and expected improvement in profitability.

Table 3-1-5

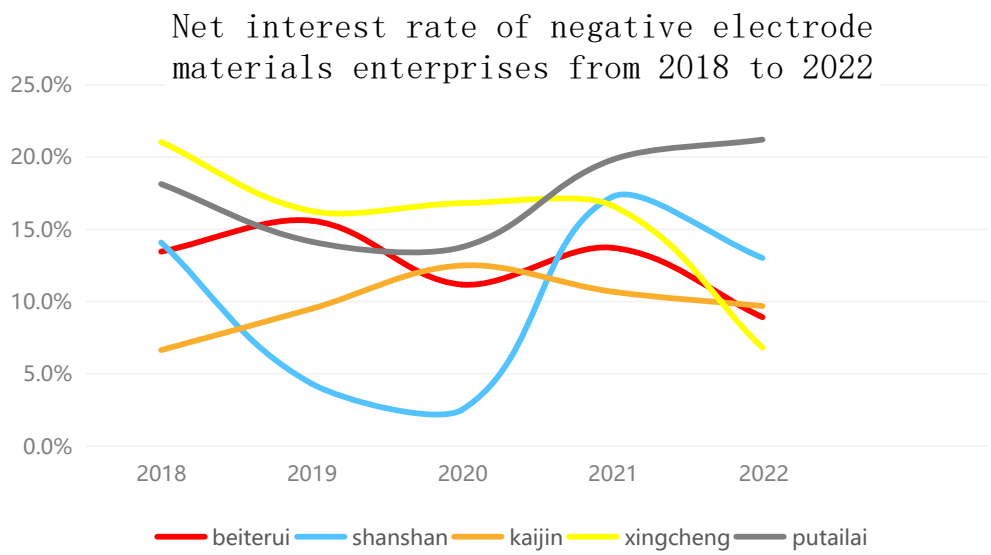


Source: Annual report of listed company

In terms of technical reserve, defang as a leading enterprise in PRD, has strong technical strength and has obtained 130 invention patents authorization, leading the industry.In the field of ternary lithium materials, Rongbai Technology as the industry leader, by 2021 Rongbai Technology has authorized 60 invention patents for invention patents, maintaining a leading position in the industry technology.

The profitability of negative material head enterprises is stable and improving, and the output growth of PRD enterprises is leading. Three PRD corporate net interest rates have a small pullback in 2022. Beitrui's customers cover the world's leading battery enterprises, significant scale effect, net interest rate maintained at 10% level all year round. Xiang Fenghua started to supply LG Chem in 2020 and bulk supply Samsung in 2021. The net profit margin increased rapidly and remained at a high level after 2019.

Table 3-1-6



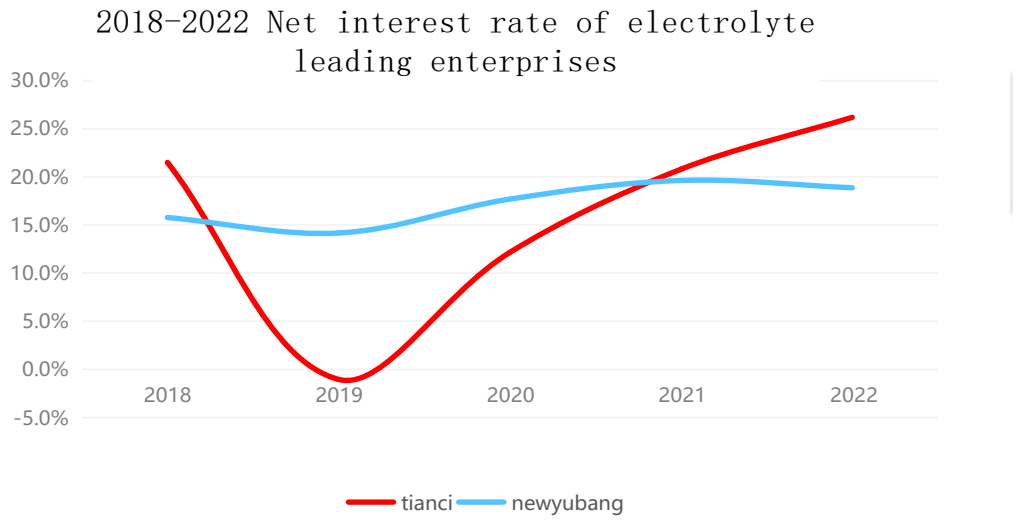
Source: Annual report of listed company

The overseas export of Chinese Anode material enterprises continues to increase, and PRD has become an important production base of Anode material in the world. Seven of the top nine companies in terms of global shipments of Anode material in 2022 are Chinese companies, while PRD's Beitrui, Dongguan Kaijin and Xiang Feng Hua rank 1st, 6th and 9th, respectively.

The net interest rate of leading enterprises in the diaphragm is stable and improving, the output performance of the industry is differentiated, and PRD enterprises grow substantially. Dry diaphragm market is small and competitive. Star Source material has entered the wet diaphragm market, and its profitability has also picked up, with a net interest rate slightly lower than Enjie shares. In terms of output, Xingyuan materials performed well in both wet and dry diaphragm markets, achieving the highest year-on-year growth in the industry. The dry diaphragm market continues to consolidate its leading edge while the wet diaphragm market leapt to the third place in the industry.

The profitability of electrolyte leading enterprises has improved, and the output growth of PRD enterprises leads the industry. In 2022, PRD enterprises Xinzhoubang and Tianci Materials will have a net profit margin of 38% and 37% respectively in electrolyte. The head enterprises in the electrolyte industry are generally in a stable position of output growth. Among the top six enterprises in output, the top three with the highest year-on-year growth rate are PRD enterprises. Tianci Materials has an earlier layout in the field of lithium hexafluorphosphate and is the global leader in this field.

Table 3-1-7



Source : Organized according to company quarterly reports

3.1.4 PRD power battery industry upstream analysis summary

In terms of market structure. As the power battery market expands further, the four major battery materials will continue to grow at a rapid pace. At the same time, the new capacity of leading enterprises is gradually released, and the market concentration is expected to remain high and continue to improve. PRD battery industry developed earlier, battery material enterprises have strong strength, in lithium

iron phosphate cathode materials, negative materials, electrolyte, dry diaphragm and other fields have a number of industry leading enterprises. However, under the background of ternary lithium battery rapidly occupying the mainstream of the market, ternary lithium materials and wet diaphragm markets are also expanding rapidly, while PRD enterprises have insufficient technology accumulation in these fields and relatively lack influence.

In terms of market conduct. In the early stage, the expansion was rapid, and the new capacity was gradually released. The overall expansion of the four battery materials market is stable and declining. PRD enterprises are accelerating the layout of upstream projects, ensuring the quality of their own products and reducing costs by improving the supply capacity of upstream raw materials, and stabilizing their position in the industry.

In terms of market performance. The net interest rate of the four PRD battery material enterprises is generally stable and rising. However, compared with other industry leaders, the net interest rate is low because PRD enterprises focus on relatively traditional fields and mature technologies, and the market competition is relatively full. In terms of output, PRD enterprises seize more market share by virtue of relatively more competitive prices and higher growth rate than the industry average.

3.2 Research on SCP Paradigm of PRD Power Battery Industry midstream

The midstream reaches of the power battery industry mainly include the assembly and production of power battery packs.

3.2.1 Analysis on Market structure of PRD power battery industry midstream

Table 3-2-1：2018-2022 Market share ranking of China's power battery companies Market Share:M/S

	2018		2019		2020		2021		2022	
Rank	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**
1	CATL	41.2%	CATL	50.6%	CATL	50%	CATL	52.1%	CATL	48.2%
2	BYD	20%	BYD	17.3%	BYD	14.9%	BYD	16.2%	BYD	23.5%
3	Guoxuan	5.4%	Guoxuan	5.5%	LG	6.5%	CALB	5.9%	CALB	6.5%
4	Lishen	3.6%	Lishen	3.1%	CALB	5.6%	Guoxuan	5.2%	Guoxuan	4.5%
5	Farasis	3.4%	EVE	2.6%	Guoxuan	5.2%	LG	4.0%	sunwoda	2.6%
6	BAK	3.1%	CALB	2.4%	Panasonic	3.5%	svolt	2.1%	EVE	2.5%
7	EVE	2.2%	SAIC	2.3%	EVE	1.9%	TAFEL	1.9%	svolt	2.1%
8	Guoneng	1.4%	Farasis	1.9%	REPT	1.5%	EVE	1.9%	Farasis	1.8%
9	CALB	1.3%	BAK	1.1%	Lishen	1.4%	Farasis	1.6%	LG	1.8%
10	CENAT	1.1%	sunwoda	1%	Farasis	1.3%	sunwoda	1.3%	REPT	1.5%

source: SNE Research

The technical barriers in the battery industry are high, and leading enterprises form a binding relationship with large vehicle enterprises to share R&D investment and expand production scale. In the future, the competition pattern of China's battery market will change with the hot sales of electric models of their respective bound car companies. At the same time, under the influence of product quality, technology choice, capacity threshold and other factors, small and medium-sized enterprises gradually withdraw from the market. PRD's power battery midstream enterprises will face fierce market competition.

Globally, the total installed capacity of global power batteries will increase by 92.5% year on year to 517.9GWh in 2022. CATL accounted for 37% of the market, up nearly 11% from 2020, ranking first for six consecutive years. South Korean companies have climbed rapidly in the rankings, and Chinese companies in the second tier have been challenged to some extent. Four Chinese firms, including BYD, CALB, guoxuan and sunwoda, ranked in the top nine. The market share and ranking of the five Chinese companies on the list have increased in the past two years. The three Korean battery companies ranked second, fifth and sixth respectively, with LG ranking second in the world thanks to Tesla's demand, while Samsung SDI and SKI's ranking fluctuated. Japanese company Panasonic also made the top nine. In general, the global power battery pattern continues the competition among China, Japan and South Korea. In terms of leading enterprises, the market share CR3 of CATL, LG and BYD will reach 64.2% in 2022, down 0.5% compared with 2021, indicating that the market competition is more intense. In 2023, the installed capacity of CATL, LG and BYD is expected to reach 88.8GWh, 87.8GWh and 90GWh respectively, and the industry CR3 will continue to maintain a high proportion.

Table 3-2-2：2018-2022 Global market share ranking of power battery enterprises Market Share:M/S

	2018		2019		2020		2021		2022	
Rank	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**	**Supplier**	**M/S**
1	CATL	26%	CATL	25%	CATL	26%	CATL	33.0%	CATL	37.0%
2	Panasonic	21%	LG	25%	LG	22.7%	LG	19.7%	LG	13.6%
3	LG	14%	Panasonic	16%	Panasonic	20.2%	Panasonic	12.0%	BYD	13.6%
4	BYD	8%	Samsung SDI	9%	BYD	6.6 %	BYD	8.7%	Panasonic	7.3%
5	Samsung SDI	8%	BYD	6%	Samsung SDI	5.8%	SK On	5.7%	SK On	5.4%
6	AESC	3%	SKI	5%	SK On	3.2%	Samsung SDI	4.8%	Samsung SDI	4.7%
7	Guoxuan	3%	AESC	2%	CALB	2.8%	CALB	2.6%	CALB	3.9%
8	SKI	2%	CALB	2%	AESC	2.5%	Guoxuan	2.2%	Guoxuan	2.7%
9	CALB	1%	Guoxuan	2%	Guoxuan	2.4%	sunwoda	0.9%	sunwoda	1.8%

Source : GGLL

Catl generates 80% of its demand from its home market, with revenue outside China already reaching $11.2 billion in 2022. In 2022, BYD will rank second in the market share of power batteries in China. Most of the power batteries produced by BYD are supplied to BYD itself. In the future, if BYD wants to maintain the first gradient in the installed share of battery field, it needs to expand the scope of customers. The second tier of the power battery market includes Panasonic, CALB, Samsung SDI, guoxuan, sunwoda and EVE, among which sunwoda and EVE are PRD enterprises.

3.2.2 Analysis on Market conduct of Power Battery Industry midstream

In 2020, power battery enterprises have actively sought to form binding relations with vehicle enterprises and build interest alliances. Similar to the relationship between traditional automobile enterprises and parts enterprises, the binding relationship between power battery enterprises and new energy vehicle enterprises can help oems effectively control costs, accelerate the progress of supporting research and development of battery factories, help them seize market share, and bring a deep moat for battery factories.

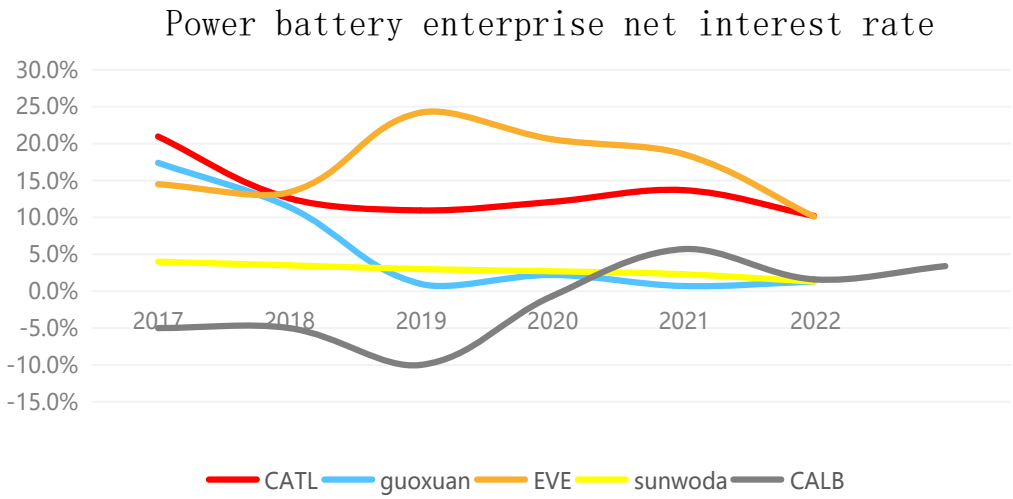
In the alliance with overseas vehicle enterprises, PRD enterprises are the main force. BYD is increasing the proportion of batteries it supplies to Audi. sunwoda batteries have entered the supply system of Volkswagen in Germany. EVE also struck a supply deal with Daimler in 2018 and has delivered lithium-ion batteries to the German company in bulk.

Power battery enterprises also improve the competitiveness of enterprises from the downstream of the industry, through the distribution of upstream raw material supply control costs. In September 2019, CATL bought an 8.5 per cent stake in Australian lithium miner Pilbara. LG Chem established a cathode material production base in South Korea in 2019, and the self-sufficiency rate of cathode materials is expected to reach 40 percent in the future. In terms of PRD enterprises, BYD lithium iron phosphate materials will account for 25% of the market in 2022.

3.2.3 Analysis on Market performance of PRD power battery industry midstream

From 2017 to 2022, the installed capacity of power battery enterprises in China and South Korea grew the fastest, and the net interest rate of CATL and EVE among Chinese enterprises was relatively high, indicating that the technological innovation ability of Chinese enterprises was increasingly emerging. PRD enterprises BYD and sunwoda also play an important role. Penghui Energy and other second-tier PRD power battery enterprises have a low net interest rate, fail to develop rapidly with the industry, and gradually quit the ranks of China's leading enterprises. In the future, PRD power battery enterprises will continue to differentiate, and the leading enterprises with strong profitability, rich customers and technical resources will be able to further participate in the international market competition. Other enterprises will be eliminated if they cannot make breakthroughs in customers and technology.

Table 3-2-3



Source: Annual report of listed company

PRD power battery enterprises lead technological innovation in the industry and drive Chinese enterprises to enter overseas markets. EVE's export revenue has grown significantly, with EVE's overseas business revenue reaching 1.55 billion yuan in the first half of 2020, up as much as 142% year on year. From a technical point of view, the new technologies launched by PRD further supplement the shortcomings of electric vehicles. For example, BYD's blade battery increases the volume energy density of power batteries by more than 30% and reduces the cost by 30%.

3.2.4 PRD power battery industry midstream analysis summary

In terms of market structure. With the continuous expansion of the market, the power battery market structure still maintains the pattern of competition between China, Japan and South Korea. Specifically, in the Chinese and global markets, Chinese enterprises maintain a leading position, with the highest number of enterprises and market share. BYD, sunwoda and EVE have gained a firm foothold in China's TOP10 ranks, while the battery enterprises in the second cascade of PRD need certain changes to avoid being gradually eliminated in the fierce market competition.

In terms of market conduct.At present, the mainstream market conduct in the power battery market is to form a binding relationship between battery manufacturers and automobile enterprises, build an interest alliance, coordinate layout, enhance the stability of both industries, and strengthen technical barriers. At the same time, it is also to the upstream layout of the industry, improve the ability to guarantee raw materials and reduce costs. PRD companies BYD and EVE have made moves in both directions and can maintain their position in the industry in the future, but further efforts are still needed.

In terms of market performance. In 2022, the installed capacity of power battery enterprises in China and South Korea will grow the fastest, and the net interest rate will be relatively stable and maintain a high level. The technological innovation ability of Chinese enterprises has begun to show, and PRD enterprises play an important role in the process of going overseas. But PRD power battery companies are also continuing to diverge. Enterprises with strong profitability and rich customers and technical resources will further participate in the international market competition, while enterprises in the second cascade will be eliminated in the competition process if they cannot achieve breakthroughs in customers and technology.

3.3 Research on SCP Paradigm of PRD urban agglomeration power battery industry downstream

The downstream link of power battery industry mainly includes battery recycling, and this section takes battery recycling enterprises as the research object.

3.3.1 Analysis on Market structure of PRD power battery industry downstream

When the power battery capacity decays to less than 80% of the rated capacity, the power battery cannot meet the power and endurance requirements of the electric vehicle. In 2022, the scale of retired power batteries in China was 36.2GWh. Research firm Markets and Markets predicts that the global market size of power battery recycling will reach 12.2 billion US dollars by 2025, and further grow to 18.1 billion US dollars by 2030.

Figure 3-3-1

The existing enterprises in the field of power battery recycling can be divided into three categories: professional recycling and processing enterprises, battery material manufacturing enterprises and power battery manufacturing enterprises. The most important recycling methods are cascade utilization and recycling. Lithium iron phosphate batteries take cascade utilization. Ternary lithium batteries can realize the recycling of nickel, cobalt, lithium and other valuable metals through disassembly and recycling of raw materials. PRD enterprises started early in the field of power battery recycling. In the second batch of 22 enterprises that meet the Industry Standards and Conditions for Comprehensive Utilization of Waste Power Batteries of New Energy Vehicles released by the Ministry of Industry and Information Technology in 2020, nearly half of the members are closely related to PRD. GEM, Guanghua Technology and Brunp have relatively mature operations, showing obvious advantages. However, the power battery recycling market as a whole is still in its embryonic stage, only a few enterprises in the market have achieved commercial breakthroughs, and the layout of many enterprises is not perfect.

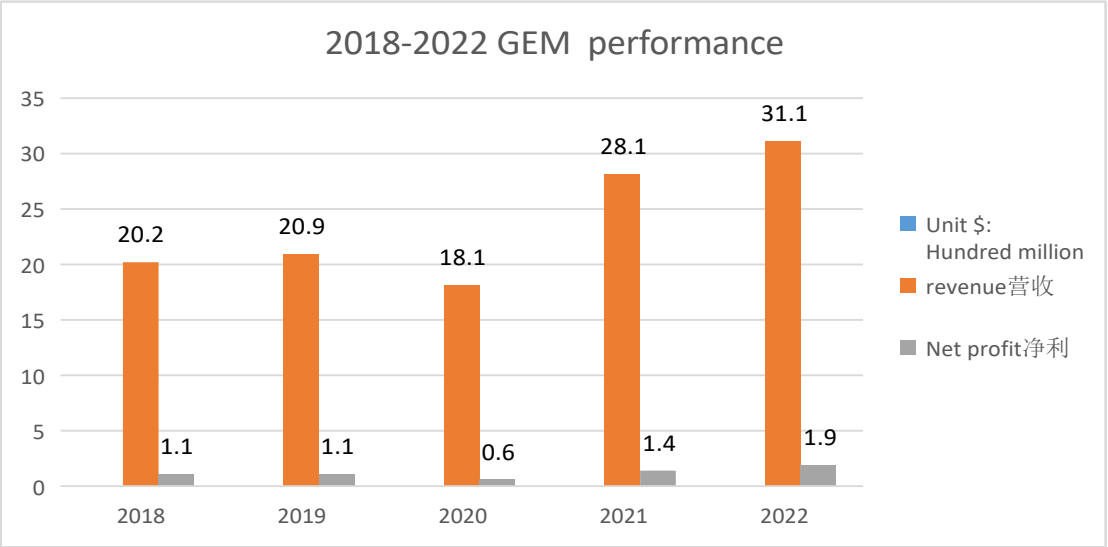
3.3.2 Analysis on Market conduct of PRD power battery industry downstream

In 2015, BYD cooperated with GEM to build a power battery cycle system of "material reengineering - battery reengineering - new energy vehicle manufacturing - power battery recycling"; Through the introduction of CATL equity investment, Brunp, on the one hand, has won a large number of waste battery resources for itself, on the other hand, it has also helped CATL to open up the upstream and downstream of the industry, enhance the control of battery recycling, and improve the discourse power in the field of battery materials.

3.3.3 Analysis on Market performance of PRD power battery industry downstream

At present, the enterprises in the field of battery recycling (such as BYD and CALB) also have business in other fields, and rarely report the performance in the field of battery recycling separately. The market performance of battery recycling is mainly studied in GEM and Brunp.

Table 3-3-2



Source : Annual Reports of Listed Companies

In terms of profitability, GEM's revenue has basically maintained positive growth since 2018, and the market development is relatively stable, which shows that the market scale of power battery recycling is gradually expanding.

In terms of the processing capacity of used batteries, GEM has built 7 battery material remanufacturing centers and 3 power battery recycling cascade utilization centers nationwide, and the annual recycling volume of used batteries accounted for 10% of the total scrap volume in China. Brunp has an advantage in waste battery recycling and renewable resource recycling capacity in Asia, with revenue of $1.31 billion in 2020 and $3.09 billion in 2021.

3.3.4 PRD power battery industry downstream analysis summary

In terms of market structure. The recycling industry has a huge space for future development, and the market is still in the embryonic stage. The development of the three types of related enterprises is also in the preliminary layout stage. PRD enterprises have a relatively rapid market layout in recycling and cascade utilization.

In terms of market conduct.Because of the high correlation between cascade utilization related technology and battery. Therefore, cascade utilization enterprises generally choose to cooperate with battery enterprises for development. At present, PRD power battery enterprises have been in the forefront.

In terms of market performance. PRD enterprises layout recycling market earlier, with certain technology accumulation, in a leading position in the industry. The gross profit margin of the enterprise is relatively stable, and the profit scale has expanded with the growth of the market. However, the overall economic benefits of the industry are low, indicating that China's battery recycling technology is not mature, and the policy support system is not perfect.

CHAPTER 4
RESULTS AND DISCUSSION

Through the combination of literature research and case analysis, this paper explores the PRD power battery industry from multiple angles. Using the SCP paradigm of industrial organization theory, this paper analyzes the relationship among market structure, market conduct and market performance of PRD power battery industry, and confirms that the development situation of PRD power battery industry is good at present.In the upstream four major materials, midstream battery manufacturing and PACK, downstream battery recycling and other aspects, has been connected into a complete industrial chain. In the global market competition, technological innovation, capacity expansion, upstream and downstream integration and other aspects have strong competitiveness.

Three problems were also found. 1. Enterprises lack the ability to follow up cutting-edge technologies. In some technical links, the response is slow, there is a risk of being eliminated by the market; 2. Some enterprises with first-mover advantage failed to expand customers and accumulate technology, and now they are gradually falling behind; 3. The region itself lacks natural resources needed for production and has the problem of unstable industrial supply chain. In view of this, four development countermeasures are proposed.

1. Combined with the industrial advantages of each PRD city, coordinated development, layout industrial chain agglomeration, and build a world-class power battery manufacturing base. 2. The state should build new research and development institutions such as power battery innovation center and new energy vehicle technology innovation center, encourage focus on the frontier field of power battery, strengthen technology reserve and cultivate core competitiveness.3. Europe was slower to respond to the previous round of developments. In the future,

more policies will be issued to support the development of power battery enterprises in the region. In view of the fact that China's power battery industry has become mature, Chinese government departments should fully mobilize various financial service entities to increase support for policies in key areas such as solid-state batteries, new electrolyte additives and cobalt-free cathode materials to help enterprises achieve their development goals.4. Accelerate the integration of industrial research and development system with the world, establish international technology cooperation window, absorb global high-end technology, deepen the degree of resource sharing, and form an international industrial center.

Through this study, the application of SCP paradigm is enriched and the gap in the existing literature on the case study of PRD power battery industry is filled. It points out the problems faced by the industry in its development, which will help the industry and enterprises to correctly recognize the market situation, avoid the potential crisis, and grasp the development trend. The relevant experience extracted in this paper can also provide practical experience and development model reference for the development of power battery industry in other regions.

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