IndustriALL Research Report

CHINA'S NEW ENERGY VEHICLE BATTERY INDUSTRY

By Boy Lüthje, Zhao Wei, Danielle Wu and Siqi Luo

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Prof. Dr. Boy Lüthje, Institute of Public Policy, South China University of Technology

Dr. Zhao Wei, ESSCA School of Management

Danielle Wu, Institute of Public Policy, South China University of Technology

Dr. Siqi Luo, Sun Yat-Sen University Contact: luethje@ipp.org.cn

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Executive Summary

This report analyzes major structural changes and trends in the emerging battery industry for New Energy Vehicles (NEV) in China, in order to understand the changes in the supply chains of global carmakers and challenges for promoting social and environmental sustainability in this sector.

Industry structure and global supply chains

The automotive sector is undergoing a massive transformation that can be compared to the break-up of Fordist production models and the subsequent globalization of major manufacturing industries in the 1980s and 1990s, electronics in particular. Vertical disintegration and re-integration is at the core of this process. On the one hand, the existing production systems of global carmakers and their hierarchical supplier pyramids may gradually lose their core role in the automotive sector. New sources of production know-how are emerging, which is no longer exclusively controlled by traditional carmakers. NEV batteries are a key element in this transformation.

Compared to the 1990s, the conditions of "globalization" have changed considerably. Emerging economies are no longer extended workbenches for low-cost production. They have accumulated substantial technological and production know-how at various stages and become important players in global innovation. In the NEV and battery sector, China is the global lead market, the major producer and a key innovator.

Global supply chain development, therefore, no longer is a top-down process, controlled by the leading global brand-name companies in industrialized countries, but multidimensional in the sense of distributed centers of innovation and industrial players controlling different segments. The global carmakers are no longer the undisputed leaders of industrial development in the auto sector.

Company strategies and vertical integration in China

China caught the opportunities of the disruptive transformation of the automotive industry and gained a leading position as a first mover in NEV-battery making. This development was based on a large sector of battery suppliers for consumer electronics, computers and mobile phones. China now has a complete Lithium-ion battery (LIB) value chain for NEV, from upstream materials production to midstream manufacturing of cells and modules, as well as downstream applications in mobility and various other fields, such as grid storage, lighting and solar energy. Within the automotive sector, Chinese battery producers are becoming important players as providers of core components, reaching out into other battery technologies such as hydrogen fuel cells.

This report explains in detail the factors of this development, including China's national industrial policy, the country's market size, continuous improvement of legislation and regulation, the existence of vast natural resources, and the strategies of key industrial actors. In contrast, industrialized countries have privileged and protected the traditional car industry and delayed the development of NEV until very recently. Global automakers benefited from the massive growth of the traditional car market in China between 2000 and 2017, but ignored the massive need for innovation deriving from climate change and the ecological problems of car traffic.

The dominant strategy of Chinese firms can be described as **specialized vertical integration** across the industrial chain, including LIB cell production, mining and refining, cell materials and components, electronics assembly, packaging, final assembly of NEV and building of charging stations. Major firms expand and integrate their activities into various stages of the production system, but vertical integration remains within the battery value chain and around the specialized field of battery or electricity storage.

Environmental sustainability of NEV-battery production

This report describes China's economic and social framework to ensure the environmental sustainability of battery manufacturing. Given the systemic weakness of trade unions, business associations and civil society organizations, environmental standards are mostly secured by laws and regulations provided by the state at various levels. China has established a comprehensive framework of environmental rules and legislation, which is comparable to industrialized countries or more advanced in some aspects. However, the enforcement of national laws and regulations through local governments differs considerably, giving room to loopholes and violations of existing laws.

As will be explained, the industrial policies to upgrade NEV manufacturing have important effects of upgrading for battery manufacturing, both with regard to product safety and recycling. China's current effort to build a comprehensive system of NEV-battery recycling are ambitious and advanced compared to similar efforts in developed industrial countries.

One reason is that the unexplored negative environmental consequences of NEV-based mobility, such as rising electricity consumption, shortage of raw materials and growing electronic waste, have become more visible in China than elsewhere.

However, there remain a number of open questions, which need further systematic study – especially the environmental impact of battery plant location, recycling facilities and of materials mining and refining.

Worker rights and trade union representation

The rapid expansion of NEV production in China has mostly been driven by private-owned firms with background in the electronics industry. This process is described as "Foxconnization" of car manufacturing. It brings lower wage and employment standards to the Chinese automotive industry, which has been dominated by state-owned enterprises and joint ventures.

Whether this development will induce a general trend to lower wages in core automotive manufacturing in China, or whether the existing segmentation of employment conditions between first-tier carmakers and the lower tiers of supplier networks will be increased, remains to be seen. Certainly, this will depend on the degree to which official trade unions and government labor bureaus will be involved at the local level, and whether existing labor laws and standards are properly implemented.

Consequences for global supply chains may be different from the electronics industry, since the emerging NEV sector does not yet have a clear division of labor between technology-defining brand-name firms and manufacturers. In addition, the motives to relocate factories and build global production network are not - or not only - to reduce labor costs, but rather strategic considerations concerning market proximity and co-operation with global carmakers. Electronics contract manufacturers themselves are becoming important players in production networks for NEV with substantial technological resources. Some of them have already established joint ventures with global carmakers in China, such as Foxconn with Stellantis.

The open questions to understand the production regimes of major battery firms and to be studied by industrial trade unions are mostly related to the general framework of labor relations in China, namely

- compliance of companies with existing labor laws and regulations;
- supervision of labor standards at the local level;
- trade union representation and collective bargaining;
- wages and wage systems;
- vocational training and workforce development.

In the concluding chapter, the major implications of our analysis with regard to key strategic questions from the perspective of international trade unions will be summarized. Our recommendations are based on the view that in a rapidly developing global industry such as

NEV battery production, "decoupling" from or vs. China is impossible, and global governance around environmental sustainability, decent working conditions and shared prosperity is mandatory.

1. China's automotive industry in transition

1.1 Transformation of the global car industry

The current changes in the car industry are not merely technological in nature. They mark a comprehensive break in the production models, innovation strategies and company structures that were established with the Fordist model of mass production since the 1920s and revised under the so-called lean production revolution of the 1980s and 90s. The changes can be compared to the transformation of other mass production industries in recent decades, in which globalization and restructuring had led to a fundamental reversal of production models and value chains. Information technology (IT) and electronics manufacturing (Borrus and Zysman, 1997; Lüthje, 2001), textile and garment (Bair, 2002), footwear, and furniture (Gereffi and Korzeniewicz, 1994) have been at the forefront of such developments.

With the transition to NEV, the automotive sector is facing similar deep-ranging shifts in the international division of labor and the shape of global production networks. However, today major emerging economies, China in particular, are playing a leading role in this transformation. While production costs and wages are still relatively low, China plays a leading role in the process of innovation and has become an indispensable partner for industrialized countries in the transformation of the car sector.

The automotive industry has often been portrayed as the lead example of Fordist mass production and consumption, linked with relatively high wages and strong bargaining relationships between employers and trade unions (Aglietta, 1979). In the wake of the economic crisis of the mid 1970s, the auto industry was at the center of restructuring of production models through lean production and modularization (Womack ea., 1990), which enabled a refurbished model of car consumption with greater variety of models, market differentiation and segmentation, and significantly shorter model cycles. This pushed mass production and thereby capital concentration in the car industry to ever larger dimensions and limited flexible specialization as an alternative pathway of capitalist production and growth (Piore and Sabel, 1984).

Related to the basic trends of technological change, three sets of disruptive factors can be traced, which are relatively independent from each other, but interrelated. These have been broadly described in business, labor, and academic literature:

- <u>New energy vehicles:</u> Electrification of the car promises a solution to the major environmental problem of car-based mobility, i.e. carbon emission. It therefore offers a lifeline of survival for the established growth model of the car industry, but renders much of the know-how and SK Innovationlls of established carmakers obsolete and radically reduces the labor content of car making (by as much as 50% according to earlier estimates, HBS, 2012). It also brings in new players from the field of new energy components, especially car batteries and power management systems.

- <u>Digital driving and control systems:</u> This can be seen as the most direct manifestation of information technologies becoming a key factor in restructuring. Digitalization of driving brings in the big players of the IT industry, their models of innovation and market control, and their financial power, including venture capital. This development challenges the traditional innovation cycles of the car industry and implies a potential shift of market control from brand-name manufacturers to providers of key components of digital driving systems and their related partners in big data and artificial intelligence (McKinsey, 2016).

- <u>Digital mobility</u> is the main driver breaking up the model of private car ownership as dominant norm of consumption (Tyfield 2018). It shifts the center of innovation downstream to the networks and applications that enable the shared use of cars, comparable to other industries with platform-based models of innovation, such as mobile telecommunications (Thun and Sturgeon, 2017). In such environments, the hardware and its brand name are becoming a less important element of competition, rather than software, apps and networks. At the same time, car sharing and other mobility networks de facto become public infrastructures (Srnicek 2017) that affect the requirements for the development of the hardware product.

1.1.1 Towards a new industry structure

These disruptions "from outside" are related to the internal problems of the traditional accumulation regime of the neo-Fordist car industry, accompanied by an expected new push of automation through the digitalization of car production (Pardi e.a., 2019). The industry has been plagued by structural overcapacity in recent decades, particularly in the wake of the global financial crisis 2008-09. China and other emerging economies provided the "safety valve" to maintain global growth in the face of severe disruptions in developed country markets, helping to postpone substantial restructuring of the dominant accumulation regime (Lüthje and Tian, 2015). This was backed by tacit coalitions between global carmakers, mainstream political parties, and trade unions to protect the car industry and related jobs.

Today, conditions can be compared to the IT and electronics industry on the eve of the personal computer and Internet "revolutions" in the late 1980s. The existing global champions, large integrated computer, chips and telecommunications equipment makers such IBM, Siemens and Fujitsu, were challenged by newcomers such as Microsoft, Intel and Cisco. These companies not only pioneered sweepingly disruptive technologies, but they created a whole new model of innovation and industry organization that became known as "Wintelism" (Borrus and Zysman, 1997).

This model was based on vertical disintegration and specialization, industry-wide modularization of core components, and the separation of product innovation from manufacturing. Brand-name control transitioned from final assemblers to component suppliers. The "assembly-oriented model of innovation and market control" (ibid.) in mass production industries such as electronics, automotive or textiles and garments, was fundamentally challenged. Manufacturing was shifted to a new brand of vertically integrated contract manufacturers such as Flextronics and Foxconn that created massive manufacturing sites in Mexico, Eastern Europe, South East Asia and China (Lüthje e.a., 2013a).

1.2 Structure and growth model of the Chinese car industry

China's automobile industry, now the largest in the world, has seen a double transformation during the past two decades.

The 1990s were dominated by the massive restructuring of the major state-owned automobile firms of the Mao period on the one hand, and the emergence of first-generation joint ventures between local state-owned holding companies (such as Shanghai Automotive) and foreign carmakers (such as Volkswagen) on the other. The car market was relatively undeveloped during that period (Thun, 2006).

Since around 2000, a huge influx of foreign investment introduced a new series of joint ventures and a major modernization of production under various models of lean production. This surge of investment in advanced technologies and manufacturing systems has created a production base comparable with that of industrialized countries, including a growing array of design and development activities (Lüthje and Tian, 2015).

The production networks in China's automotive sector today mirror the globally dominant model of flexible mass production of standardized car models in large varieties. It is based on modular, company-specific platforms promoted by the major producers on the side of production, and on private car ownership of large sectors of the population on the side of consumption. The joint ventures mainly have served the Chinese domestic market. The key policy goal was to transfer state-of-the-art technology and manufacturing know-how to Chinese carmakers (ibid.).

The production networks of the car industry are based on the lean-production model with relatively slim core factories for car assembly and global-local pyramids of first-tier system suppliers and second- and third-tier parts manufacturers (Zhang, 2015). In China, the automobile industry's supply pyramid is embedded in the highly segmented structure growing out of the sector's trajectory of capitalist transformation.

The top layers of production networks, assembly of cars and some strategic components (engines in particular), are controlled by joint ventures. The middle and lower tiers of the supply pyramid are mostly owned by private local, foreign and overseas-Chinese investors, usually with little access to high-level government resources. Multinational first-tier car suppliers have expanded rapidly in China, including sizeable research and development operations. However, the overall picture remains dominated by heavy cost competition and labor-intensive production processes with relatively limited industrial upgrading (Lüthje and Tian, 2015).

Against this background, the growth regime of China's automobile industry is split into a capital-intensive high end, dominated by Chinese SOE and their multinational partners, and a low end in which extensive strategies of accumulation prevail. The automotive industry represents a predominantly *state-capitalist mode of regulation* at the core, formed by the joint ventures of Chinese state-owned carmakers with multinational brands and top-tier global car suppliers from North America, Europe and East Asia. At the same time, a number of smaller carmakers under private or "hybrid" ownership, such as Geely, Chery or BYD, have emerged that have been able to challenge the large SOEs in some important markets. These companies have developed extensive production networks at local and regional levels and receive support from interventionist local governments to build supplier networks, infrastructure and technological resources.

Compared to the relatively coherent state-capitalist core of car making, the ownership structure of China's automotive supply sector remains scattered. Among first-tier suppliers, global firms with foreign direct investment or in joint ventures with Chinese SOE are dominant. At the lower tiers of the supply chain privately owned and hybrid companies of all sizes can be found along with overseas Chinese enterprises from Taiwan and Hong Kong. They are mostly allied with local governments that provide cheap land, workers' dormitories and "flexible interpretations" of laws and regulations.

This oligopolistic structure was relatively efficient in guiding the massive restructuring of the Chinese car industry in the late 1990s and its great leap forward into state-of-the-art production technologies and networks. State-capitalist regulation has also been critical to support the massive geographic expansion into greenfield sites in central and Western China since the crisis 2008-09, as well as the globalization of Chinese state-owned carmakers as investors and shareholders in multinational car companies (such as Beijing Automotive in Daimler and Dongfeng in PSA, Lüthje and Tian, 2015).

Given the challenges in the global car industry, however, serious doubts have been voiced over the efficiency of this framework. The state-capitalist model not only curbs competition and encourages oligopolistic pricing behavior, it also limits innovation. The major players put substantial resources into the adaptation of foreign car models to the Chinese market, but have shown little interest in developing indigenous innovations in car technologies, components and concepts. Chinese government policies therefore has increasingly shifted to increased support to newcomer companies in the NEV sector and also to digital driving.

1.3 New players in the Chinese NEV sector

The entry of rapidly growing new players into China's automotive sector is reshaping the traditional model of state-capitalist regulation. It brings in innovative firms from the non-state-capitalist sector of the car industry (independent car and NEV makers as well as component producers), from the IT industry, and from global and Chinese car suppliers. Significantly, the Chinese government relies on such new industrial actors, taking account of the success stories of the country's IT and other industries that followed pathways different from the joint-venture model.

The IT sector provides a model for the current transformation of the automotive sector. The successful development of Chinese IT brand-name firms, such as Huawei, Lenovo and ZTE to national and global lead firms was achieved in the absence of or in competition with joint-venture strategies. In the telecommunications industry, joint ventures of SOEs with global players such as Ericsson, AT&T and Siemens were designed in the 1990s to trade technology transfer for market access. The Chinese partner firms reaped substantial profits from making and selling foreign-branded telecom equipment in rapidly growing urban markets, but they failed to develop brand-name products and services for the huge markets in rural areas. This was left to newcomer firms such as Huawei who combined expertise in undeveloped markets with rapid adaptation of leading-edge technologies from the evolving Internet equipment industry in Silicon Valley.

Since the Chinese government began to expand the NEV sector by imposing production quota of fully electric vehicles on carmakers (see section 2), a significant change in investment has taken place, while incumbent carmakers suffer from sluggish sales and mounting overcapacity. In 2018, the Chinese market for passenger cars contracted for the first time in recent history, in the first half of 2019 sales of passenger cars fell by 14% (Financial Times, 2019a). The massive buildup of capacity on the part of joint ventures, that has dominated the scene since 2008-9, has come to a halt. In some cases, such as Beijing-Hyundai, plant closures became imminent (Automotive News China 2019a).

On the other hand, independent carmakers and NEV producers grew rapidly. Geely in particular has opened three plants in the past two years, bringing production capacity to 1.7 million cars per year. In 2017 alone, 14 NEV startups in China were granted production licenses and most of the companies have started building factories. According to the China Association of Automobile Manufacturers, annual capacity for the production of pure and plug-in-hybrid electric cars hit 2 million in 2019, and a large number of NEV startups are expected to start production until 2022 (Automotive News China, 2019b).

1.3.1 The emerging competitive structure of China's green car industry

The emerging landscape of new indigenous players in the Chinese car industry can be grouped by technology clusters, business models and their relationship to the world-market:

Independent car and NEV makers with a background in the auto industry, such as Geely, Cheery, JAC and BYD. With its diverse product portfolio of small and medium-sized cars as well as buses and utility vehicles, BYD has sold more electric vehicles than any competitor has worldwide. Geely has established a highly ambitious strategy to convert its Volvo brand completely to NEV, embarking on joint internal component development and use of a low-cost production system created by Geely (Financial Times, 2017). At the end of 2020, Geely entered an alliance with Foxconn to provide contract manufacturing of cars, eyeing new entrants from top-tier global IT firms into NEV (Taipei Times 2021). Most of the independent car and NEV makers have their own factories, and are vertically integrated within Chinese-style conglomerates. They run extensive local production networks, designed to leverage cost advantages for local players.

Digital car and NEV startups, backed by Internet giants, global venture capital and Chinese business tycoons, such as NextEV/NIO, LeEco/Faraday, and Baoneng. Most of these companies focus on development of high-end vehicles, similar and in competition to market leader Tesla. Most of these ventures are highly speculative and have received ample publicity. In the light of some spectacular bankruptcies their market and financial success still needs to be tested. Different from Tesla, these companies focus on design and development and use contract manufacturers to assemble cars, especially their electronic components. In the wake of Tesla's success in China after the coronavirus crisis, a new wave of speculative investment into Chinese NEV startups has occurred (Automotive News China 2020).

Integrated new energy (BYD) and battery producers. Here, Chinese companies clearly have the strongest position in the world market (Fraunhofer, 2016). BYD is a battery maker by tradition, originally a supplier of LIB for computers and smartphones to Foxconn and other large electronics manufacturers. In 2017 the company was classified as the biggest producer of Li-ion batteries globally, leveraging vertical integration effects from various end markets such as cars, buses, IT or solar and energy management systems. The second lead firm is CATL, a previously unknown battery maker from Ningde, a rural city in Fujian province, where China's president Xi Jinping once served as local party secretary. The company has massively expanded production with plans to become the world's largest producer by 2020. As part of a major globalization effort, CATL announced the construction of a factory in Erfurt, Germany, with an initial capacity of 14 gigawatt-hours per year to supply BMW, VW and other major European carmakers with LIB cells (Dongfang IC, 2019). In addition, China's major electronics making areas, the Pearl-River Delta in particular have extensive clusters of small and medium-sized battery makers with production experience from the electronics industry (IPRD 2018). This lineup is completed by large Chinese manufacturing operations of leading battery makers from Korea and Japan in China. In 2017, eight out of the thirteen major LIB manufacturing sites in the world were in China (Sanderson e.a., 2017).

Car suppliers play a key role in the transformation of innovation and production networks. The situation in this sector in China mirrors the segmented structure of supplier pyramids under the joint-venture model. First-tier transnational suppliers are engaged in the development of digital driving systems, and they are preferred partners for the Chinese big three Internet companies. Bosch has formed a strategic alliance with Ali Baba, Continental with Baidu (Automotive News China, 2017). But there is no Chinese car supplier of significance that could play the role of system integrator and potential global champion in the NEV and digital supply chain.

Electronics contract manufacturers, most of them based in Taiwan, already play a major role in supply chains for car electronics and are moving into NEV and digital car electronics. EMS giant Foxconn has operations in car electronics including some major facilities in the United States and acts as a supplier to Tesla, among others.[1] Given the increasing commodification of NEV and digital car components, large IT contract manufacturers appear as potential mass producers for components of driverless vehicles and NEV. Contract manufacturers are also securing positions as investors in start-ups of all kinds, Ali Baba and Foxconn invested $350 million in an NEV startup named Xiaopeng (Automotive News China, 2018). In the fall of 2020, Foxconn announced a new technology platform for NEV and a network of alliances with Geely and Chinese start-up NEV makers, aiming at the replication of its contract-manufacturing model in the electric car sector (Financial Times, 2020).

Overall, it can be said that the forms of vertical integration, production models and value chains are in rapid transformation and highly unstable. Obviously, the NEV industry in China is evolving along a modularized structure, composed of a set of subindustries that provide the major components and systems.

In this context, new regional centers of production and innovation and new power relations between the central and the local state are emerging. Most of the new players and industry

[1] Foxconn CEO Guo Taiming stated that "Tesla EVs are virtually made in Taiwan" (Digitimes Jan 8, 2018)

segments are located outside traditional centers of car manufacturing. Shenzhen and the Pearl-River Delta (with BYD, Tencent, Foxconn and a huge base of electronics manufacturing), Hangzhou (with Geely and Ali Baba), and Fujian Province (with CATL) can be seen as core locations. As we will explain below, the government-industry relations in those regions are different from the traditional centers of the auto industry with their strong state-capitalist traditions. The new centers are governed by relatively open forms of regulation (Lüthje 2021b), with arms-length relationships between activist local governments and privately owned firms.

1.3.2 Changing production models

Traditional carmakers - globally and in China - have recently responded with massive investments into NEV. Companies such as Volkswagen or Ford have begun to produce electric versions of most car models in the near future, VW announced that 50% of its sales in China will be NEV (Automotive News China, 2019c). VW has created its own global platform, and concentrates NEV manufacturing in two dedicated factories in Shanghai and Foshan (Guangdong Province).

Traditional carmakers try to use their manufacturing expertise to keep the old model of vertical integration intact. Yet, their production strategies for NEV are driving new forms of modularity. VW, BMW and other global carmakers source battery cells externally under large-scale contracts with CATL and other East-Asian producers and limit their own production activities to the assembly of battery cells into car frames (2019 field interviews).

At the same time, carmakers are aggressively pushing cooperation and cost sharing. In a major alliance with Ford, VW will license its newly developed MEB platform for electric vehicles to Ford and potentially to other carmakers in the future (Financial Times, 2019b).

The restructuring of production systems and value chains also opens up considerable potentials of flexible specialization. Production of specialty cars, delivery trucks, buses, and public transport systems creates a large array of growth opportunities for NEV. In these markets, as well as in passenger NEV, volumes tend to remain relatively small. Changes in technology as well as government regulations and standards require frequent changes in model lineups and components.

To cope with such insecurities major Chinese firms tend to keep their operations highly integrated, but with low degrees of automation. BYD in particular, pursues a strategy to produce batteries and components for new energy systems of all kinds (including smart phones, urban grids, and solar systems), among which cars are only one downstream product. Under this model, new energy technologies are employed in a large variety of products and systems, economies of scale are mainly leveraged on the side of battery production (IPRD, 2018).

2 Emerging value chains in the Chinese LIB Industry

According to a report dedicated to the Lithium-ion battery value chain, published in 2016 by the Joint Research Centre (JRC), the European Commission's science and knowledge service, the main segments of the LIB value chain are composed of:

- raw and processed material production (cobalt, natural graphite, silicon metal, lithium);
- cell components manufacturing (cathode materials, anode materials, electrolytes, separators);
- cell manufacturing;
- battery pack manufacturing;
- electric vehicle manufacturing;
- recycling.

The full value chain structure of the LIB industry can be illustrated by Figure 1. The above different segments are grouped into

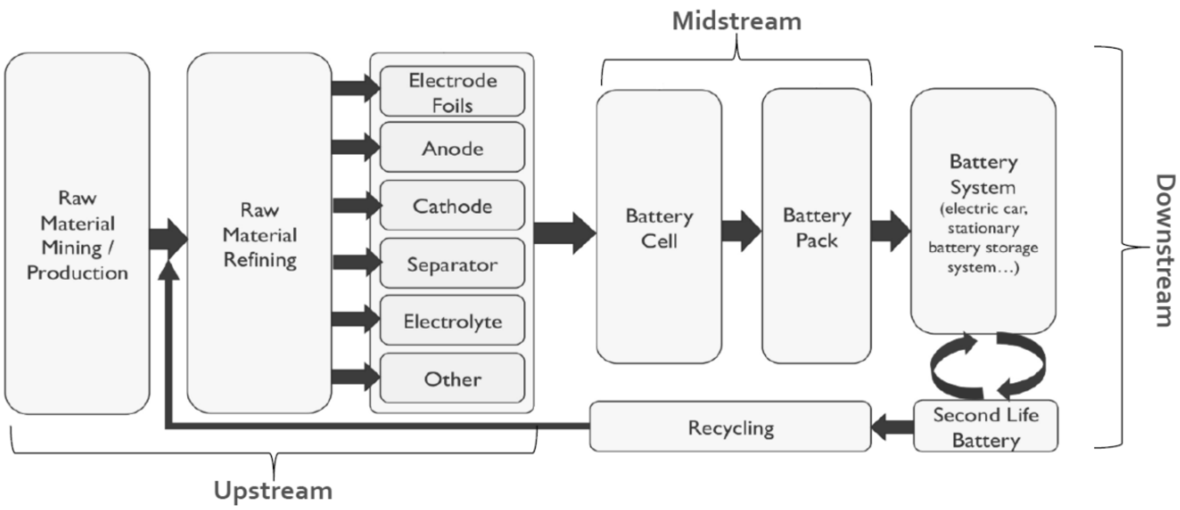
upstream activities (raw material mining and production, raw material refining, battery material production)

midstream activities (battery cell, battery pack production),

and downstream activities (battery system production and installation, battery storage, battery second life, recycling, etc.).

Within a relatively short period of time, China has developed all the upstream, middle stream, and downstream segments. Thereby, the country has the competitive advantage of possessing the whole LIB value chain.

Figure 1: The Value Chain of LIB Manufacturing



Source: Status of the Rechargeable LIB Industry Report, July 2017, Yole Développement, with authors' adaptation.

2.1 China's national development strategy for NEV

More than a decade ago, China has defined the NEV industry as one of its key strategic development domains, in order to meet the future challenges of resource, energy, environment, industrial transition and urbanization. In 2012, the State Council of China released the "Energy Saving and New Energy Vehicle Industry Development Plan (2012-2020)", clearly setting out the phased goal: by 2020, the production capacity of pure electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) will reach 2 million units, with cumulative production and sales exceeding 5 million units.

Since then, the NEV industry in China has started its fast development, supported by advantageous industrial policies and subsidies from both central and local governments. In 2018, China accounted for more than half of the global EV sales and some Chinese traditional

OEMs - BAIC, SAIC and Geely - are now among the world leading EV makers. This huge domestic NEV market backed up battery capacity growth.

2.1.1 Rapid growth, but looming overcapacity

Largely due to the domestic NEV industry development, the LIB industry in China has also experienced a fast growth since 2014. Benefiting from favorable policy and generous subsidies of the Chinese government, many firms have entered different positions along the value chain of the LIB sector in a very short period. BYD planned to reach 90 GWh production capacity by the end of 2020. CATL, representing 50% of the domestic market in 2019, would have 54 GWh production capacity by the end of 2020. Other leading battery firms (Gotion Hi-Tech, Tianjin Lishen, Farasis Energy, National Energy, BAK) are also increasing their apacity to 20-40 GWh for the same period[2]. Besides using specialized battery firms, most OEMs are vertically moving to battery self-supply or building joint ventures with battery firms.

According to the adjusted growth targets proposed by the MIIT (Ministry of Industry and Information Technology) in December 2019, by 2025 NEVs will contribute to about 25% of annual vehicle sales in China, instead of the initial 20% in the 2012-2020 NEV Development Plan. The main reasons for the adjustment are increasing production capacity, improved technological level, growing global demand, as well as providing a guide to further investments and technology upgrading. Under the government's plan of 8.75 million NEVs sales by 2025, power LIB demand will reach more than 500 GWh from China alone.

Even though the NEV sales slowed down in 2019, the power LIB sector still registered a significant annual growth: total sales reached 75 GWh, with an increase of 15.3% compared to 2018; installed capacity reached 62 GWh, representing an increase of 9.2% compared to 2018. In 2019, 73 % of the global total LIB capacity was located in China, compared to the second place of the US with 12% share (Rapier, 2019).

Figure 2: Market growth of NEV-used LIB in China

Source: Gao Gong Industry Institute (GGII), March 10, 2020

The rapid power LIB capacity expansion by Chinese battery producers, however, has resulted in a relatively low utilization rate, as NEV sales still present only about 5% of the total vehicles sales annually, thus causing the problem of overcapacity. According to the statistics published by Gao Gong Industry Institute (GGII), the total production of power LIB in China reached 44.5 GWh in 2017, 8.1 GWh higher than the actual demand; the overall inventory accounted for

[2] Author's calculation from company reports and announcements

about 18.2% of the total output; the national power battery capacity utilization rate was only 40%.

In 2018, only the leading firm CATL's production capacity utilization rate reached a higher level of 76%; BYD's capacity utilization rate was only 54%; the capacity utilization rates of the next eight biggest Chinese power LIB firms were even lower, ranging from 6% to 34% . Behind the exciting electric vehicle market development, the data indicates on the contrary that the power battery sector is already suffering from severe overcapacity.

2.1.2 Changing Subsidy Policies

The NEV subsidy policy in China has been a catalyzer for the rapid growth of the electric vehicle production and all its components. Concretely, the NEV subsidy policy covers different aspects, the most essential ones including technical requirements, purchase tax exemption, and practical advantages - priority in registration, city drive and parking.

From 2010 to 2019, China has issued more than 70 regulations at the national level regarding the NEV industry, more than any other country. Importantly, there has been a tightening of technical requirements enabling the allocation of subsidy. At the beginning, the only requirement to qualify for a subsidy was a minimum energy capacity for the power battery of at least 15 kWh. Today, the requirements are much broader, they encompass vehicle performance (maximum speed and minimum range), battery density as well as vehicle energy efficiency (Alochet M., 2020).

Parallel to the tightening of technical requirements, the Chinese government announced to fully cancel its direct financial subsidy by the end of 2020 and has been gradually doing so since 2016, with a yearly reduction rate of about 20%. In April 2020, due to the continued NEV market slow down and a severe economic situation caused by the Covid 19 epidemic, the Chinese government decided to postpone the full cancellation of subsidy to 2022, allowing longer time of adjustment.

The government's plan is to substitute the direct financial subsidy by a market-based credit mechanism, which combines a NEV quota and a credit trading system for carmakers. The New Energy Vehicle Mandate, which came into force on April 1, 2018, imposed NEV credit targets as 10% of the conventional passenger vehicle market in 2019 and 12% in 2020 (with continued gradual growth for following years) for any carmaker with over 30 000 vehicles manufactured locally or imported yearly in China (ICCT, 2018).

For the moment, this mechanism is at its initial period of deployment, and the trading system still in construction. The NEV credits mechanism aims to stimulate intensification of R&D and technological densification in the Chinese automotive industry, from battery power, to electric range and finally to the electric range + battery power + energy consumption tripod. The MIIT announced that it will continue to intensify requirements in the future (Muniz, S.T.G.e.a., 2019) .

However, with the gradual phasing out of buyer subsidies, the NEV market in China has visibly slowed down since the second half of 2018. Especially for the second half of 2019 - due to the continued subsidy reduction at both national and local level as well as the complete elimination of subsidy for vehicles with a driving range under 250 km - the total sales of NEV were only about 1.2 million units, decreasing 4% compared with the same period in 2018. With the impact of Covid 19 on consumption power, the NEV sector has further suffered from a very weak demand for the first half of 2020.

Taking out the consequences of the pandemic, NEV producers are still facing big challenges with the full cancellation of direct subsidy in view. One solution is to reduce the sale price of the vehicle in order to win a bigger market share and at the same time guarantee a minimum production volume to reach the economies of scale. As battery represents over 50% of the overall cost of an electric vehicle, battery firms are also among the most impacted in the NEV value chain.

54 bis, route des Acacias
CH 1227 Geneva
Switzerland
Tel: +41 (0)22 308 50 50
info@industriall-union.org
www.industriall-union.org

OEMs generally requested battery firms to reduce the price by 20% to 40% during 2019. In the same year, the average battery pack price in China reached $147/kWh, which was the world's lowest. Price pressure has become a major structural market feature.

2.1.3 Sectoral Policy: From Infant Industry Protection to Market Competition

Back in 2016, in order to prevent foreign competitors and protect its nascent LIB industry, the Ministry of Industry and Information Technology (MIIT) introduced the catalogue of "Regulations on the Standards of Automotive Power Battery Industry", commonly known as the "white list". According to this document, only battery models fully owned by local battery makers were included in the list and by consequence qualified to receive government's NEV subsidies.

Since all the recommended NEV battery-cell suppliers were domestic, this measure in fact pushed the Japanese and South Korean battery firms, such as Panasonic, LG Chem and Samsung, out of the Chinese local market. This regulation provided a window period for Chinese firms to build their own comparative advantages, through methods including technology absorption, economies of scale, supply chain lock-up effects, etc.

On May 22, 2018, the new "white list" for the first time included three Chinese Joint Ventures of foreign battery leaders, namely Samsung (50%), LG Chem (50%) and SK INNOVATION (40%), releasing a strong signal of reducing protectionism and promoting stronger market competition. At the same time, China has effectuated the full opening up of its automotive market for foreign investors; no form of joint venture is required anymore when foreign companies invest in the Chinese auto sector. Tesla was the first to fully invest and own its Gigafactory in Shanghai.

Since then, foreign battery firms, especially leaders from Japan and South Korea, have made a strong comeback in the Chinese market, investing in new battery plants aiming to supply to OEMs of their own nationality and Chinese ones.

- Panasonic has planned to build up to 9 GWh/year battery capacity in Dalian (Liaoning), about 35 GWh/year battery capacity in Suzhou (Jiangsu) and 30 GWh/year in Wuxi (Jiangsu);
- LG Chem has planned to build in Nanjing (Jiangsu) 23 GWh/year battery capacity by 2023;
- Samsung SDI wants to reach a total of over 35 GWh/year battery capacity in Xi'an (Shaanxi), Tianjin and Wuxi (Jiangsu) by the year of 2021;
- SK INNOVATION has opted for the form of battery joint ventures, one with BAIC in Changzhou (Jiangsu) of 7.5 GWh/year capacity and another with EVE Energy in Yancheng (Jiangsu) of up to 28.5 GWh/year capacity.

Currently, these foreign battery firms are mainly supplying foreign owned OEMs or joint venture OEMs. LG Chem sells its battery to Tesla and the former joint venture of Dongfeng-Renault (now fully owned by Dongfeng). SK INNOVATION supplies to the joint venture of BAIC-Benz. Panasonic and Sanyo supply to the joint venture of GAC-Toyota. Samsung SDI is the supplier of SF Motors. With the progressive market opening, the foreign suppliers will compete with Chinese battery firms both in the domestic and overseas markets.

As the protectionist policy changed and entry barriers were lifted, one big challenge for Chinese battery firms now is the strong competition from foreign battery firms, which still have some comparative advantages in the core technologies and quality management. Besides traditional strategies including stronger R&D efforts to improve battery technology - larger production scale to reduce the unit price, better battery system solution to reinforce overall performance -, Chinese battery firms are also considering other strategies for downstream integration and cooperation, such as forming alliances and joint ventures with OEMs or Tier-1 car suppliers.

We will describe more examples in the following section. These different strategies will accelerate the consolidation of the battery sector and lead to deeper industry evolution.

The market opening goes along with the reduction of subsidies, showing a typical Chinese pattern of industrial policy adaptation. In the LIB sector, the industry policy evolved throughout different development stages. After the initial phase of protecting the nascent industry, a sufficient number of domestic players had been established. With a potential risk of overcapacity, policy support changed to stimulating core technology innovation and consolidation among battery makers. Chinese policy makers hope that market selection will promote firms that offer the best performance, have better innovation capacity, and show higher competitiveness.

2.2 Strategies for Value Chain of LIB firms in China

As macro-industrial policy initially enabled the rise of China's electric vehicle battery industry, firm-level strategies and choices progressively relayed to this impetus. Indeed, battery firms in China quickly deepened their capabilities in mass production and R&D of battery technologies and products. Driven by demand, a large quantity of products became available in the market, and production capacity has kept increasing fast. Strong user (NEV car) – producer (NEV battery) – supplier (NEV components) linkages and interactions are created through the active development of mainstream firms, further strengthening the localization of NEV battery value chain in China.

CATL has set up battery joint ventures with all big Chinese OEMs, including BAIC, Dongfeng, Changan, SAIC, GAC, Geely and FAW. Large capacity of production and vertical-horizontal consolidation within battery industry are creating big Chinese firms in a short period of time (CATL, BYD, Gotion High-Tech, Tianjin Lishen, EVE Energy, etc.). Big firms take all.

As a result, the number of battery firms has significantly decreased, from about 240 in 2015 to only 69 by the end of 2019; this number will continue to decrease in the coming years. At the same time, a trend of internationalization, through different strategies (greenfield investment, M&A, strategic cooperation, etc.), is also observed among leading Chinese battery firms, which demonstrates China's deepening insertion into the global value chain.

CATL is building its first overseas battery plant in Germany, with a planned capacity of 14 GWh by 2022, in order to supply to European OEMs such as BMW, Volkswagen, Daimler, Jaguar Land Rover and PSA. CATL also formed a long-term strategic cooperation agreement with Bosch to produce Bosch 48-volt batteries. Gotion Hi-Tech's wholly owned subsidiary and Tata AutoComp from India signed an agreement to jointly design, develop and produce LIB cells, packs and BMS. BYD is considering building a battery cell factory in the UK to supply Jaguar Land Rover. Envision AESC, the battery industry fund of Envision Group (a Chinese pioneer in energy internet of things), has acquired 80% of Nissan's power battery business.

2.2.1 Specialized Vertical Integration

The dominant practice of core firms in the Chinese LIB sector can be analyzed as a value chain strategy. **Table 1** summarizes the strategic moves of all relevant players in terms of their activities. The horizontal axis represents value chain segments, the vertical axis the different types of relevant firms, and the in-tables describe the firms' strategic positioning and entries.

This value chain strategy is characterized by two combined aspects:

- **Growing through vertical integration.** Except some firms in specific niche segments such as equipment and support parts, almost all firms in the LIB sector grow their business through vertical integration. Upstream firms integrate forward to downstream segments, including battery recycling and energy storage. Downstream firms integrate backward to upstream segments such as materials or components. Midstream firms undertake both forward and backward vertical integration. New entrants are active in various segments, with preferences to battery making and complete NEV assembly. Vertical integration is realized by acquiring or creating new assets by means of mergers and acquisitions, strategic alliances, industrial co-operations, and greenfield investment.

- **Competition based on industrial specialization.** When LIB firms grow through vertical integration in the value chain, they do not abandon their original segments and business (the grey colored areas in Table 1). On the contrary, firms continue to compete in their original market and try to become more specialized in their original segments as bases for further market expansion and growth. Through rapid scaling up of production capacity and progressive technological development of new products, they gain more resources and capabilities by exploiting and augmenting their existing assets.

Table 1: Firms' Strategies of Developing NEV Battery Value Chain in China

Value chain segments / Firm category	Raw material mining and refining	LIB materials producing	LIB cell, module, pack, and BMS manufacturing	Electric powertrain system production	NEV assembly and production in China	Battery charging station	Reuse and recycling of LIB	Diversified energy saving and storage segments
(1) Mining and refining firms	Minmetals Jinchuan Huayou	Minmetals Jinchuan Huayou	Minmetals				Jinchuan Huayou	
(2) LIB materials producers		Corun Shanshan GHTECH Tinci	Corun Shanshan Tinci				Corun Shanshan GHTECH Tinci	
(3) Incumbent LIB manufacturers	CATL BYD Sunwoda	CATL BYD Sunwoda	CATL BYD Gotion Lishen EVE Farasis BAK Sunwoda	BYD Sunwoda	BYD Sunwoda	BYD Sunwoda	CATL BYD Gotion Lishen BAK Sunwoda	CATL BYD Gotion Lishen EVE Farasis BAK Sunwoda
(4) OEM producers of NEVs			(a) BYD, Geely, FAW, National New Energy, VW, Weltmeister, Great Wall (b) BAIC, Dongfeng, Changan, SAIC, GAC, Geely, FAW, Daimler (c) VW (Gotion), Daimler (Farasis), Geely (LG Chem), Wanxiang (A123)		BMW Tesla VW		BYD Geely BAIC SAIC BJEV Dongfeng Changan VW Daimler	
(5) Specialized recycling and dismantling firms	GEM	GEM					GEM Brunp Haopeng Miracle	GEM
(6) Startups and new players in NEV & battery industry			GREE Zhongli Evergrande Envision Baoneng		Baoneng		Baoneng Weltmeister China Tower	Baoneng Weltmeister China Tower ZTE

Source: Authors' data collection from industrial news and company announcements

As a common characteristic of the behavior of different firms, the strategic moves take place mostly within the boundaries of the LIB value chain. The field of specialization is around the battery-related technologies. The vertical integration and entry mainly are directed at various segments the segments of the battery sector, from upstream to downstream. Even for the more diversified downstream activities, they are all based on specialized production, service, and technology of power batteries for NEV. The framework of the value chain has become the major reference point for the strategy choices of firms at different chain stages of LIB in China.

As we have explained in part 1, the boundary between LIB makers and OEM carmakers is still relatively open. Previous research on OEM carmakers strategies in the battery value chain confirms that carmakers are basically seeking vertical integration (Huth, C., Wittek, K. and Spengler, T.S., 2013). Our findings in China show that not only OEMs, but also all players in the LIB value chain adopt vertical integration strategies.

The aforementioned research also found that full integration alone does not work for carmakers. Due to volume and technological uncertainties, an OEM cannot solely rely on its own in-house production, even though many OEMs defined development and production of battery packs as a core competence. In China, the adoption of vertical integration strategy by all major firms in the battery value chain resulted in the emergence of a bundle of specialized players who quickly occupy every stage of battery value chain, capable to supply OEMs with lower costs and flexibility.

Thus, the Chinese pathway of development is highly complementary to the vertical integration strategies of OEMs. It supports an NEV industry based on vertically specialized mass production of various interacting industry segments, similar to the electronics and other high-tech industries.

2.2.2 Mining and refining firms: forward integration

For mining and refining firms, their value chain integration strategy aims at consolidating their existing upstream advantages and at entering segments of battery materials production and battery recycling.

Through the past decades, Chinese mining firms have formed comparative advantages in the raw materials supply of key strategic metals used in the NEV production. At the aggregated level,

- they control over 90% of the world’s rare earth metals;
- they have made massive foreign direct investments to acquired ownerships of cobalt, nickel and lithium mines in major resource countries;
- by providing engineering, construction and operational services in other foreign firms’ mining projects, they often obtain part of the mining products in return.

Moreover, China is the world’s biggest importer, exporter and consumer of LIB related special metals (over 50%) and has been the major country driving materials use increase for the past 10 years. Chinese refining firms operate the major part of the world’s processing facilities for cobalt, nickel, lithium and graphite: China represented 35 % of world’s cobalt refining capacity in 2013 and this number grew to 62% in 2018; for refined nickel and graphite, China represents about 60% of the world’s total capacity. Also, major producers of LIB in East Asia, namely the big three Korean firms LG Chem, SK INNOVATION and Samsung SDI are heavily dependent on materials imports from China.

In the face of the current massive growth of new energy vehicle production, leading Chinese mining and refining firms actively enter downstream battery materials production and the end-of-life battery recycling.

- Huayou, the No.1 cobalt producer and supplier in China, has founded two joint ventures (JV) in 2018 with LG Chem and Korean steel maker POSCO to produce LIB materials.
- Jinchuan, the No.1 nickel producer and supplier in China, and Hunan Corun, a leading producer of LIB battery material, battery system and powertrain system, have built a JV to produce battery materials and battery system for PHEV; their clients include BYD, SAFT, Toyota and SANY.
- China Minmetals, one of the largest conglomerates in metal and minerals, has created a subsidiary, Changyuan Li Technology, dedicated to LIB battery cathode materials production, with clients including CATL and BYD.
- Besides, some refining firms, such as Huayou and Jinchuan, are also actively involved in battery recycling at the very downstream of the value chain.

2.2.3 Material Producers: forward integration

For LIB materials producers, their value chain integration strategies include moving into forward segments of battery system production and positioning in the end-life battery recycling business.

The battery materials of LIB are principally composed of cathode, anode, electrolyte, and separator. These materials are produced, or processed, from more standard refined materials (nickel, cobalt, lithium, aluminum, manganese, copper, graphite, etc.), based on the required technical characteristics of the final LIB products. They play a key role in determining battery performance, energy density, service life and safety.

With the advantage of locating in the world's biggest NEV market, Chinese producers are gradually catching up with leading Japanese firms in the subsector of high-performing LIB materials.

- Ningbo Shanshan is one major supplier in LIB materials, covering cathode, anode and electrolyte.
- Cathode supply is more fragmented, with a group of firms actively competing in the market.
- Electrolyte supply is more concentrated, with the top 5 producers taking up over 60% of the market share.

In general, LIB materials producers are located in the Southeast coastal provinces, namely Guangdong, Fujian and Zhejiang, where have emerged large industrial clusters of electronic and semiconductor products.

Among these LIB materials producers, some have entered the forward segments to produce LIB cell and system. This is the case of Ningbo Shanshan, Hunan Corun and Guangdong Tinci. Hunan Corun also develops and produces the whole package of electric powertrain system. It has founded an international R&D centre in Nagoya, Japan, which helps transfer Japanese technology and know-how with OJT (On the Job Training) for development, manufacturing preparation, and scale production of PHEV powertrain system. Some LIB materials producers, such as Shanshan, Corun, Tinci and GHTECH, are also developing new business in the battery recycling.

2.2.4 Incumbent Battery Makers: Vertical Integration

For incumbent LIB manufacturers, the value chain integration strategies are more diversified, including upstream resource supply and LIB material producing, and downstream battery reuse and recycling, and energy saving applications. BYD is a particular case with almost full value chain coverage and cross-sector integration.

While many battery makers were motivated to increase their production capacity for winning the future market, it also led to overcapacity in recent years (IEA, 2019), especially regarding low-end and old generation batteries. In the face of fierce competition, incumbent LIB manufacturers carry out both forward and backward integration, extending to both downstream activities such as NEV production/assembly and upstream activities, but always staying within the boundaries of the LIB value chain.

In forward integration, battery makers tend to diversify to different segments such as battery reuse and recycling activities, emergency power source, voltaic solar power generation, low-speed electric automotive, electric bikes, electric boats (CATL), public trams (BYD), medical energy storage, grid-use energy storage, and 5G station power supply. Some examples of flagship firms are CATL, BYD, Gotion Hi-Tech, Lishen, BAK, EVE, and Sunwanda, who all have strong moves to enter downstream segments of value chain.

- Gotion Hi-Tech is supplying LIB to Huawei's overseas communication base stations.
- EVE Energy supplied the base station backup battery to China Unicom and China Tower.
- Lishen and China Tower are cooperating on the reuse of retired LIB in the 5G base stations.
- In April 2020, CATL and Kstar (power supply and inverter) co-invested 1 billion RMB in energy storage battery and equipment manufacturing base.

All these strategic entries are typical "specialized vertical integration" or "supply chain specialization", since firms remain specialized within the battery industry and develop different applications of battery, rather than pursue inter-sectoral development into NEV assembly and construction.

Backward integration is more difficult to achieve for battery makers. Massive amounts of capital are needed for upstream resource investment and supply, only the biggest players can afford this. CATL and BYD both have acquired key metals mining and refining business and hold ownership in battery materials firms. Since they have ambitious plans of capacity expansion, both in China and abroad, it is of crucial importance for them to secure the upstream materials supply and control the price.

The rationale behind the expansion of Chinese battery makers into upstream resource segments is to control market price volatility and resource supply security. Global lithium, cobalt, and nickel resources are under global oligopolies. Although China is rich in lithium resources, its endowment is poor, and its utilization rate is relatively low. Nickel and cobalt resources are quite scarce in China and the import dependence on foreign sources is high. Therefore, in the long run, the Chinese NEV industry and LIB sector will face resource security risks.

The prices of lithium and cobalt have been rising rapidly in the past few years, although last year there has been some price falling back. Even though the upstream prices have skyrocketed, with the on-going subsidy cuts for NEV purchase, electric carmakers continue to push down LIB purchase prices, which in turn compresses the profit margins of LIB makers. Big LIB makers who have the financial capacity to purchase foreign mining resources tend to adopt the upstream integration, in order to minimize the risks of raw material supply and price volatility.

BYD stands out as the only incumbent LIB manufacturer that has fully covered the whole value chain of the battery industry. Its business lines integrate the upstream resource supply and battery materials production, the mid-stream battery cell, pack and system production, the overall powertrain system and related electric control system, and the downstream battery reuse and recycling, power battery supply to other types of transport (tramway), infrastructure and solar power station. It is one of the leading NEV producers in the world, with diversified products (bus, passenger car, logistic vehicle, other speciality vehicle). It is also building PHEV recharging stations. Therefore, BYD has also diversified into NEV production and more generally the new energy industry, not limiting to the LIB industry.

2.2.5 OEM Car Makers: Vertical Integration into Li-ion Batteries

To secure the supply of batteries and control production costs, OEM carmakers are also trying to establish a presence in the battery production segment. As we have explained in part 1, high-volume production of LIB has been established as mass production industry of its own, but the lines of division between the battery production and final car assembly are still not fully drawn. Therefore, the strategies of OEM carmakers vary, competing and cooperating with incumbent battery producers. Some are also collaborating with battery materials producers in the battery reuse and recycling. In China, several ways can be found:

Creating self-owned battery firms. OEMs invest to build their own battery assembly facilities in order to satisfy its NEV production demand and better control the battery system design. In most cases, these battery subsidiaries still have to purchase battery cells or stacks from outside suppliers, which are more specialized in the core battery technologies. Examples of OEMs with self-owned battery supply (or in construction) include BYD, Geely, FAW, National New Energy, VW, Weltmeister and Great Wall. Great Wall is also experimenting a cobalt-free battery technology through its battery subsidiary SVOLT Energy Technology.

Establishing joint ventures with LIB manufacturers. Compared to the first option, more OEMs have chosen to cooperate with LIB manufacturers through the construction of joint ventures, often dedicated to supply to the OEM co-investor. This strategy allows OEMs to benefit from the expertise of its battery firm partner and reduce the financing pressure of the project. For LIB manufacturer, the JV also can help secure a part of market share in face of fierce competition.

The best example is CATL. As the leading LIB manufacturer in China, with over 50% of market share in 2019, CATL has gradually built JVs with all big Chinese OEMs - BAIC (2009), Dongfeng (2016), Changan (2017), SAIC (2017), GAC (2018), Geely (2018), and FAW (2019). This strategy helps CATL further secure its leading position in the LIB sector. Other examples include JVs of Geely and Changan with Corun, Dongfeng with Lishen, Changan with BYD, FAW with SK Innovation.

Entering through equity investment or M&A. Another, and faster, way for OEMs to enter battery making is through equity investment, notably mergers and acquisitions. M&A is a strategic tool of external growth for firms, especially for expansion into a new market or a new business sector. In particular, the strategy is mainly used in the context of cross-border investment between two firms from different countries.

The most interesting case is Volkswagen's equity investment in the Chinese No.3 battery producer, Gotion Hi-Tech. By becoming Gotion's largest shareholder, VW will further secure the battery supply for its NEV production in China. Another example is Daimler's acquisition of 3% shares of Farasis Energy in July 2020. At the same time, Farasis Energy will build a power battery cell factory in Bitterfeld-Wolfen in eastern Germany to supply to Mercedes-Benz.

Chinese OEMs have also made M&As in the battery sector. Geely bought LG Chem's Nanjing LIB plant in 2017, when the national policy did not allow foreign LIB producers to enjoy the same subsidy rights. Wangxiang Auto has acquired the American battery firm A123 back in 2013. Moreover, since the year 2018, China has opened out the automotive industry, allowing foreign OEMs to obtain full ownership of their subsidiary in China. Consequently, BMW increased its shareholding of its JV with Brilliance to 75%; Tesla has built its Shanghai Giga Factory; Volkswagen took the majority 75% shareholding in its electric mobility JV with JAC. This trend indicates new market dynamics and a deeper engagement of foreign OEMs in the Chinese market.

Besides the battery production business, OEMs are involved in the downstream segments of battery reuse and recycling. This also reflects the regulatory environment, as government policies regarding retired LIB and its treatment are emerging rapidly, and the circular economy is promoted. The OEMs usually collaborate with its battery suppliers or specialized battery materials firms to recycle LIB. Some of the active OEMs include BYD, Geely, BAIC, SAIC, BJEV, Dongfeng, Changan, VW and Daimler.

2.2.6 Recycling and Dismantling Firms: Backward Integration

Reuse and recycling is rapidly emerging as an important segment in the LIB value chain, Chinese firms are moving fast to take a position.

In 2016, GEM, Samsung SDI, CATL, BYD, Dongfeng, a few leading firms from battery materials, LIB manufacturing and NEV production, jointly set up a lifecycle value chain of "Battery Recycling - Material Reengineering - Battery Pack Remanufacturing - Automotive Reassembling". In 2019, MCC Ruimu New Energy started pilot demonstration project for NEV power battery recycling in the Beijing Tianjin Hebei region.

The amount of used lithium batteries from NEVs in China reached 6,000 tons in 2018 and the number is expected to reach 200,000 to 300,000 tons by 2021 (Fang, 2019). In 2018, more than 20 billion US$ has been invested in the NEV industry in China, with 25% oriented to reuse and recycling projects. Recycling has become a top issue of national industrial policies.

Specialized recycling and dismantling firms usually stay within the specialized business of reuse and recycling of LIB. GEM, Hunan Brunp Recycling (of which CATL owns 69% of capital), Ganzhou Haopeng, Huayou and GHTECH have been selected in 2018 by the Ministry of Industry and Information Technology as the first batch of 5 companies that met the "Industry Standards and Conditions for Comprehensive Utilization of Waste Power Batteries for New Energy Vehicles". Miracle has built a JV with a German specialist in the circular economy, ALBA Group, to operate together in the LIB and NEV reuse and recycling.

GEM is a particular case as the firm has vertically integrated upstream material supply business and downstream energy storage business. Started as a recycling and dismantling firm, GEM has so far signed power battery recycling cooperation agreements with 201 well-known automakers and battery factories around the world, including BYD, BAIC, NIO, Jaguar Land Rover, Toyota, Dongfeng-Honda, CATL, SK Innovation and others. With the growing amount of recycled raw materials, GEM has gradually developed technologies and know-how to produce battery materials.

Recently, GEM has entered the battery material supply system of Samsung, CATL, LG, Panasonic and other LIB manufacturers, providing them with ternary cathode material precursors containing nickel, cobalt and other elements. The firm has also developed diversified products for energy applications, including NEV charging station, energy storage battery for household and specialty vehicles. Moreover, GEM has co-invested with CATL and Tsingshan in a laterite nickel resources project in Indonesia, which will help them secure raw material supply.

Given issues such as cost and technology, cooperation between OEMs, battery suppliers and recycling and dismantling firms has become a feasible solution. As an example, Geely Group takes the lead and cooperates with Wanxiang, Tianneng, Huayou Cobalt and other OEMs, battery manufacturers, end-of-life automobile recycling and dismantling firms to jointly build a shared channel for the recycling of new energy vehicles in Zhejiang Province.

2.2.7 Startups and New Players: Vertical Entrance

For startups and new players in the NEV & battery industries, the development strategy is usually cross-sector M&A to enter into new energy vehicle and power battery production.

In most cases, the investor firm comes from a related sector: GREE (electronic appliances) which acquired 8% of Changyuan Battery; Zhongli (new material) which acquired 8.3% of BAK battery; Envision (wind power technology) which acquired 80% of Nissan's power battery business AESC and 100% of NEC Energy Devices. In a few cases, the investor firm comes from a quite different sector: Evergrande (real estate) which acquired 100% of NEVS (former Saab), 58% of CENAT Battery and holds 65% of its auto JV with Koenigsegg; Baoneng Group (real estate and financial services) acquired 63% in the newcomer automobile maker Qoros.

In other cases, a battery subsidiary is founded. Baoneng Group's subsidiary Hongpeng New Energy produces LIB and Fuel Cell batteries and plans to operate in battery recycling and energy storage applications.

Startups and newcomers are also involved in the downstream segments of battery reuse, recycling and energy storage. Newcomer Weltmeister and China Tower (telecom) cooperate in battery recycling and distributed energy and electricity usage. ZTE's new energy subsidiary has built 8 GWh LIB capacity, for the energy supply of its 5-G base stations.

2.3 Specialization and production strategies of LIB firms in China

The dominant value chain strategy of LIB firms in China is not simply to achieve vertical integration within the LIB sectoral boundaries, it consists also of the continued specialization of firms' original resources and capabilities. According to the relevant literature, business firm's competitive advantage is mainly based on its specific resource and capability configurations (e.g. Conner, K., 1991). Resources and capabilities represent the production know-how that a firm can control and use to conceive and implement its competitive strategies.

Under pressure of fierce market competition, LIB firms in China have to reinforce their initial market positioning and deepen their specialization in original segments, mainly through rapid expansion of production capacity and new design of battery product. For example, LIB cell and pack producers are typical examples pursuing simultaneously both cost-leadership and product differentiation for competition.

2.3.1 Mass Production: Resource-based Specialization

LIB cell and pack producers invest heavily to increase production capacity, in hoping to gain cost advantage via scale economies. Table 2 shows the top ten Chinese battery producers in terms of installed capacity in the domestic market for the year 2019 and the year 2018 (see Appendix 1 for a list of major companies). As illustrated in Table 1, the market is already quite concentrated and continues its consolidation, as the top 10 firms' total market share has increased from 82.85% in 2018 to 87.98% in 2019. CATL and BYD have become the two largest battery suppliers in absolute terms; for the rest of firms, their sales growth and business performance could still vary in the coming years, influenced by many market uncertainties.

Market leader CATL represents an impressive example. In the domestic market, CATL is supplying batteries to over 100 NEV makers, including SAIC, Geely, Yutong, BAIC, GAC, Changan, Dongfeng, Jinlong, and Jiangling, as well as newcomers such as NIO, Weltmeister and Xiaopeng. In the global market, CATL is also increasingly supplying to and cooperating with important OEMs, such as BMW, Daimler, Hyundai, Jaguar Land Rover, Peugeot Citroen (PSA), Volkswagen and Volvo. In February 2020, CATL officially became Tesla's third power battery supplier after Panasonic and LG Chem.

Besides its expansion in China, CATL is also investing in production capacity in Europe to supply to local OEMs. In 2019, CATL has invested about 2 billion euro for its 14 GWh factory in Erfurt, Germany by 2021 and has the intention to expand the capacity up to 98 GWh (IEA, 2019). CATL has also signed a long-term strategic cooperation agreement with Bosch to collaborate on Bosch's 48-volt battery. Other Chinese battery firms going abroad through internationalization include BYD and Gotion Hi-Tech.

Figure 3 shows more details on the capacity growth under planning. In regional comparison, Chinese firms are obviously leading the trend by investing massively in battery production capacity, with the expectation to reach more than 850 GWh by 2023 and about 1400 GWh by 2028. Leveraging comparative advantages of volume, price and experience, they also plan to largely increase battery export to other markets and supply to OEMs outside China. At firm level, current global leaders - CATL and BYD (Chinese), LG Chem, Samsung SDI and SK Innovation (South Korean), Panasonic (Japanese) are all planning to significantly increase their production capacity for the coming decade. Foreseeably, CATL and LG Chem will have a fierce competition on gaining and keeping the first place in the global market.

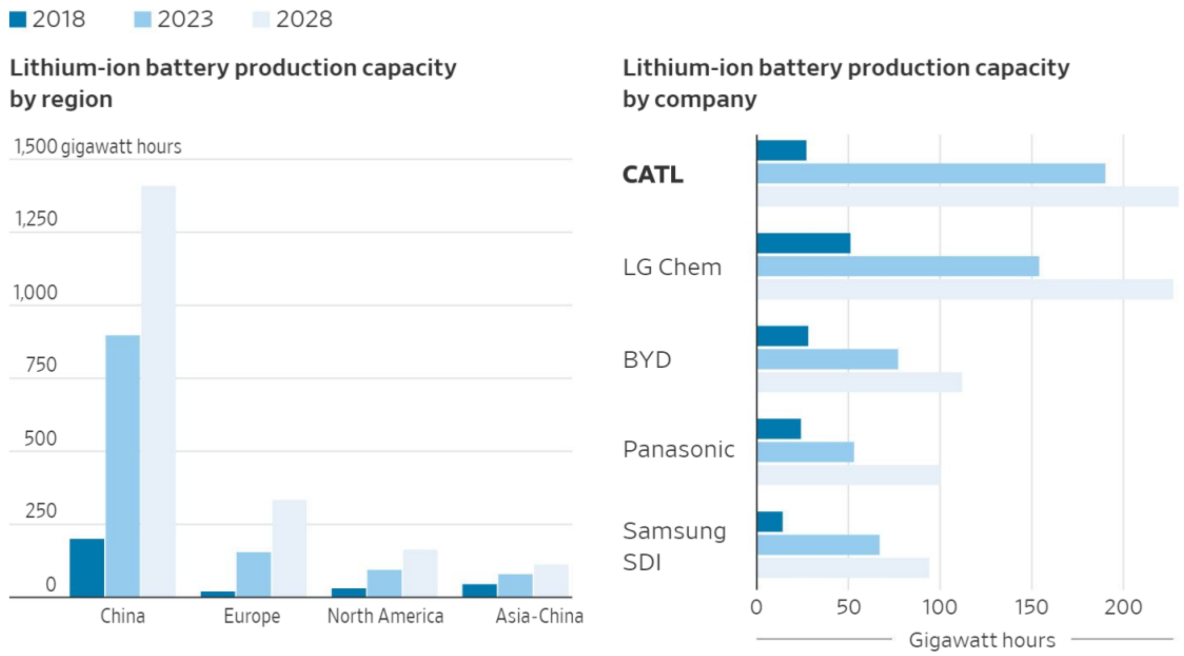
54 bis, route des Acacias
CH 1227 Geneva
Switzerland
Tel: +41 (0)22 308 50 50
info@industriall-union.org
www.industriall-union.org
President: Jörg Hofmann
General Secretary: Atle Høie

Table 2: Top 10 Chinese battery firms in terms of installed capacity

2020 Top 10	Installed (GWh)	2019 Top 10	Installed (GWh)	2018 Top 10	Installed (GWh)
CATL	31.48	CATL	32.31	CATL	23.52
BYD	9	BYD	10.78	BYD	11.44
LG Chem	6.54	Gotion Hi-tech	3.22	Gotion Hi-tech	3.09
CALB	3.77	Lishen	1.95	Lishen	2.07
Gotion Hi-tech	3.24	EVE Energy	1.84	Farasis	1.9
EVE Energy	1.02	CALB	1.49	BAK	1.74
Lishen	0.9	Farasis	1.21	EVE Energy	1.27
Farasis	0.87	CATL-SAIC	0.74	National power	0.82
Ruipu	0.64	BAK	0.69	CALB	0.72
Jeve	0.57	Sunwoda	0.65	CENAT	0.64
Total top 10	**58.03**	**Total top 10**	**54.88**	**Total top 10**	**47.21**
Total China	**62.85**	**Total China**	**62.38**	**Total China**	**56.98**
Top 10/China	**92.44%**	**Top 10/China**	**87.98%**	**Top 10/China**	**82.85%**

Source: Gao Gong Industry Institute (GGII), January 2019, January 2020, February 2021

Figure 3: LIB production capacity by region and by leading companies



2.3.2 Technological Improvement: Capabilities-based Specialization

Another significant aspect of specialization is the upgrading of technological and product design capabilities among major LIB producers. In the past, when the Chinese government pushed global automakers to help their local joint ventures develop NEVs, many joint ventures chose to give battery-cell supply contracts to Chinese local battery producers. Therefore, foreign carmakers helped local battery producers set up rigorous technical standards for their battery-cell manufacturing and boosted local battery producers' credentials as qualified NEV suppliers.

54 bis, route des Acacias
CH 1227 Geneva
Switzerland
Tel: +41 (0)22 308 50 50
info@industriall-union.org
www.industriall-union.org
President: Jörg Hofmann
General Secretary: Atle Høie

Over time, and especially under pressures from Japanese and South Korean competitors, who had technological advantage, Chinese local battery producers improved their technology and quality levels. They began to develop capabilities to renew the resource configurations in cell and pack production and design to match and even create market change. The development of Lithium Iron Phosphate Blade Battery (LIB) of BYD and the CTP (Cell-To-Pack) technology of CATL are two examples. BYD's Blade Battery is literally an improvement of product form design and product structure re-engineering, without changing the fundamental battery materials and electrochemical system. It can be categorized into the incremental innovation of product architecture. The Blade battery will be massively produced with brand new manufacturing lines of BYD in Chongqing. BYD apparently is hoping the product will be adopted and purchased by other NEV makers. With blade battery, BYD can hold a competition stand in face to CATL and other battery makers who adopt the same product innovation strategy.

"Cell To Pack" (CPT) is a new process eliminating the modules in order to increase utilization of pack space. CATL is now able to produce bigger cells and link them to make the whole battery pack directly. Both BYD and CATL hope that government can take the performance of blade battery as new safety standards to level up the barrier to entry.

2.4 Geographical structure and main locations of battery manufacturing

One major characteristics of China's emergence of battery industry is clustering of the battery manufacturing activities at regional level across the whole country. In fact, almost each provincial government has elaborated ambitious plans of developing NEV industry, including its battery supply industry, to implement the national strategic emerging sector development framework (Made in China 2025) and picks up some cities and regions as manufacturing bases. The replication of local policy of battery industry development led to emergence of industrial clusters of battery making across the country, as well as domestic redundancy and fierce competition.

Promoted by industrial policies of local governments, many battery clusters in China have two outstanding characteristics. One is that a local cluster can contain a relatively complete value chain of NEV battery making from upstream segments, such as material production, through cell and pack production, to downstream applications of battery packs to different fields, especially electric vehicles. Thus, an OEM can easily find the whole supply chain from one local cluster.

With more and more related and supportive firms joining the cluster to be close to battery makers as their clients, the cluster will mature into a "thick" manufacturing ecosystem (Berger, 2013), rich of institutions, information, resources, and capabilities, very accessible and supportive to battery firms. Industrial clusters have become pillows to the creation, business growth, and market competitiveness of Chinese battery makers. The case of the cluster in Huizhou City described below (see 2.4.2) typically represents these two characteristics.

2.4.1 Main locations of battery manufacturing in China

The "Catalog of Recommended Models for the Promotion and Application of New Energy Vehicles" issued by the Ministry of Industry and Information Technology (the 5th batch in 2018 to the 11th batch in 2018) includes 3718 new energy vehicles, and a total of more than 190 power battery companies which provide power batteries for these new energy vehicles. The geographical distribution of these companies is: a total of 112 companies in East China, accounting for 58.95%; a total of 28 companies in South China, accounting for 13.68%; a total of 23 companies in Central China, accounting for 12.10%; a total of 13 companies in North China, accounting for 6.84%; The Southwest and Northwest regions have 7 and 5 companies respectively; the Northeast has the least distribution, with only 4 companies.

As the largest geographic region in China, East China includes 8 provinces including Shanghai, Jiangsu, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, and Taiwan. It is also the region with the largest concentration of power battery companies, 112 battery companies. There are 41 power battery companies in Jiangsu Province, such as Zhihang New Energy, Xingheng Power, Tafel New Energy, Zhengyun New Energy, Jiangsu Haisida and other companies, as well as Jiaweilong Solid-state Energy Storage, which appeared in the recommended catalog for the first time, and is also located in Jiangsu Province. There are a total of 22 enterprises in Zhejiang Province, led by Aoyou Battery, Weihong Power, Wanxiang 1-2-3, Gushen Energy, and Hengdian Dongci. According to statistics in Shanghai, there are 15 companies including Delang Energy Power, Jiexin Power, Carnegie New Energy, and Jinghong New Energy. There are a total of 12 in Anhui, including Guoxuan (Goshen) Hi-Tech, Oupengbach, Wuhu Tianyi Energy and so on. Shandong has 10 companies including Yuhuang New Energy, Guojin Battery, Mofang New Energy and Shandong Weineng. Jiangxi and Fujian have 7 and 5 battery companies respectively. Jiangxi includes Funeng Technology, Far East Foster, Anchi New Energy, Hengdong New Energy, etc..

The battery giant CATL, Fujian Mengshi, and Guancheng Ruimin New Energy are located in Fujian Province.

There are a total of 23 power battery companies in the three provinces of Henan, Hunan and Hubei in central China. There are 8 companies in Hunan Province, led by Thornton New Energy, Miaosheng Power, CRRC Times and other companies. Hubei has six companies including Wuhan Zhongyu Power, Camel Group New Energy, and Dongfeng Motor. There are a total of 9 companies in Henan, such as AVIC Lithium Battery (Luoyang), Poly Fluoride (Jiaozuo), Henan Lithium Power, Henan New Taihang, etc.

North China includes five provinces and cities including Beijing, Tianjin, Shanxi, Hebei, and Inner Mongolia, with a total of 13 power battery companies. Among them, there are 7 companies in Beijing, led by Guoneng Battery, CITIC Guoan Mengguli, and Beijing Pride. 5 companies including Tianjin Lishen Battery and Gateway Power are located in Tianjin. There is only 1 company in Shanxi.

The southwest region includes 5 provinces and cities including Sichuan Province, Guizhou Province, Yunnan Province, Chongqing City, and Tibet Autonomous Region, with a total of 7 power battery companies. A total of 5 companies are located in Sichuan, including Jianxing Lithium Battery and Tonghua Technology, etc., Guizhou and Chongqing each have a power battery company. The Northwest Region includes 5 provinces, cities, and autonomous regions in Shaanxi, Gansu, Qinghai, Ningxia Hui Autonomous Region, and Xinjiang Uygur Autonomous Region. There are a total of 5 battery companies, of which only Shaanxi and Ningxia have 4 and 1 respectively. The Northeast region includes Heilongjiang, Jilin, and Liaoning provinces, with a total of 4 power battery companies. Among them, there are 2 companies in Liaoning Province; Heilongjiang Province and Jilin Province each have 1 company.

South China includes five provinces and autonomous regions including Guangdong Province, Guangxi Zhuang Autonomous Region, Hainan Province, Hong Kong Special Administrative Region, and Macau Special Administrative Region, with a total of 28 power battery companies. Battery companies are mainly located in Guangdong, with a total of 26 battery companies, led by battery pioneers such as BYD, Yinlong New Energy, Tianjin New Energy, EVE Lithium Energy, BAK Battery, Penghui Energy, and Zhenhua New Energy, Sunwoda, EPower Energy, Chuangming Battery, Maike New Energy and other battery companies in the official recommended catalog. There are 2 companies in Guangxi, including Zhuoneng New Energy. In Guangdong, all battery companies are located in its Pearl-River Greater Bay Area, mainly deployed in cities of Guangzhou, Shenzhen, Nanhai (Foshan), and Huizhou. Among these key cities, Huizhou has totally 10 companies forming a cluster with complete value chain lcoally, which is the focus of the section below. Some of the key companies in each region are shown in Figure 4.

Figure 4: Main locations of battery manufacturing in China

Beijing: National Power Battery; CITIC-Guo'an Gu Li ; SinoHytec; Haibo Sichuang Technology; Zhixing Hongxin; Zhixing Hongyuan

Tianjin: Yinglaide; Lishen; Jeve; Hawtai-EVE

Shanxi: Changzheng

Henan: CALB; DFD Group; Henan Lithium Power Source; Shunzhihang

Hubei: Troowin; DFG; Liwei Renewables

Hunan: Soundon New Energy; Melsen Power

Heilongjiang: Harbin Guangyu Battery

Jilin: FAW-Volkswagen

Liaoning: BMW-Brilliance

54 bis, route des Acacias
CH 1227 Geneva
Switzerland

Tel: +41 (0)22 308 50 50
info@industriall-union.org
www.industriall-union.org

President: Jörg Hofmann
General Secretary: Atle Høie

Shandong: Mofang; Yuhuang; Guojin; Wina Battery; Zibo Guoli;

Shanghai: DLG Battery; ATBS; Hope New Energy; Shanghai Volkswagen; SAIC Motor

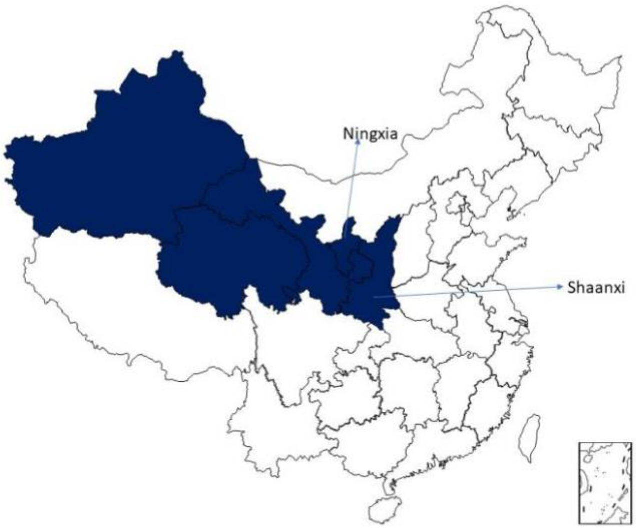
Fujian: CATL; Epower; Jiudian

Jiangsu: Phylion; Chunlan; Youlion Battery; TENPOWER; Horizon New Energy

Anhui: Gotion High-Tech; ETC Battery; SinoEV

Jiangxi: Fraisis; Far East Battery; Anchi New Energy

Zhejiang: Microvast; Tianneng Power; Chaowei; CRRC New Energy;WM Motor



Ningxia: Longneng Technology

Shaanxi: Tesson; Xinghua Electronics; Banghua; Samsung Huanxin

Guangdong: BYD; EVE; BAK; Sunwoda; GAC Group; Teamgiant; Cham; TIG

Guangxi: Zhuoneng Renewables; Sunwatt Battery

2.4.2 Example of regional battery cluster: Huizhou in the Pearl-River Greater Bay Area

As one of the core cities in the Pearl River Greater Bay Area, Huizhou is located in the southeast of Guangdong Province, with neighbors as Shenzhen and Dongguan to its south and west. Huizhou has established two pillar sectors – electronic & information technology industry and petrochemical industry. For years, Huizhou has been the number one supplier in the field automotive on-board information service and products (in-car GPS) in China. Its policy emphasis on the automobile industry has boosted investment in production of relevant new products such as electric vehicle batteries, with new manufacturing technologies as digital equipment, Internet of Things (IoT), big data, etc. The NEV battery sector development is based on its long tradition and strong foundation in electronic component (consumer electronic battery) industry, experiencing a distinct trajectory.

Huizhou's IT sector was traditionally dominated by large state-owned enterprise or holding groups, such as TCL, Desay and Huayang. In recent years, many private and foreign-invested firms relocated their plants and production facilities from Shenzhen and Dongguan to Huizhou, because the costs of land and labor became intolerable, especially in Shenzhen. For electronics, batteries and other emerging industries, the firms in Huizhou carry out little R&D activities and focus mainly on manufacturing of raw materials and key components, some produce complete products. Therefore, Huizhou's industrial structure is characterized by specialized clusters of supply chains, concentrated geographically in certain areas. The structural transformation to supply chain clusters also happens in traditional sectors such as shoes, garments, and textiles.

Huizhou has long history of production capabilities accumulated in IT-battery supply chains. The local governments battery cluster policy contains a long list of items, including permission of establishment of an industrial park and various related supportive policies; developing a more complete local industrial chain to create conditions for the migration of corporate headquarters from Shenzhen to Huizhou; providing talent and financial support for production expansion; speeding up project approval and simplify approval procedures; providing financial support for technology research and development, and encourage enterprises to expand R&D centers; attracting OEMs to set up subsidiaries; tax incentives for innovative start-ups; and financial subsidies and loan facilities, etc. However, as typical for China, labor-related policies, vocational training and improved work and wage standards in particular, are not included in this list.

Huizhou's automobile industry is mainly composed of firms manufacturing power batteries, automotive electronics, auto parts, wire harnesses, and engines, as there is no firm yet for complete electric vehicle production (OEM). The NEV battery segment has formed a relatively complete local value chain and been able to stand by its own. In addition to raw materials, the battery value chain in Huizhou covers the production of chemicals, precursors, cathode active materials, cathodes, and battery cells, modules, packs, and battery management system (BMS). The manufacturing of battery cells is the key segment. Battery packs consist of battery modules, electrical connections, and cooling equipment. Together with BMS, packs are delivered as complete battery products for various usages, mainly electric vehicles, but also possibly for energy storage and others (**Table 3**).

Table 3: Battery firms in Huizhou cluster forming complete supply chain

	Raw materials and components					Battery manufacturing and assembling				Related and supportive industries		Battery applications and usages		
Sections of EV battery value chain	Mining ore	Anode material	Cathode material	Electrolyte	Separator	Other (adhesive, binder, etc.)	Cells and modules	BMS	Packs	Structural components (tabs, insulator, containers, etc.)	Equipment	Complete electric vehicles (passenger and commercial)	Stationary Energy storages	Reuse and recycling
Haopeng Technology							Cells of NCA							
Desay Blue Micro New Energy								Now only focus on BMS						
Yinghe Technology											Front-end and back-end equipment, especially for laser cutting/ slitting, winder/ calendaring, electrode shaping, MES, complete intelligent assembly line, etc.			
Kedali Precision										Structural parts and electric box structural parts for car batteries and storages				
Yineng Electronics								Own BMS	Pouch pack					
Battery NM														
BYD							Cells of ion battery, NCA, NCM	Own BMS	Prismatic design	Battery cover		Own brand electric cars and buses		
EVE Lithium Energy							Cells of cobalt acid lithium, NCM- nickel and manganese, with anode, phosphate Li-ion	Own BMS	Cylindrical, prismatic, and pouch batteries					
Sunwoda							Cells of NCA and NCM	Own BMS	Prismatic and pouch batteries					
E-Power Energy							Cells of lithium acid manganate	Own BMS	Pouch battery for electric buses					

Local NEV battery manufacturing firms in Huizhou occupy all sections of the supply chain from upstream to downstream. For example, BYD, EVE and EPOWER are all leading firms in terms of technology capabilities and production capacities in their respect market segments. EVE manufactures battery cells and packs and applies battery products to NEV power train and energy storage systems. EPOWER explores to use new cathode materials to substitute imports and develops battery management systems with its own property rights. Its products are used to supply hybrid batteries for usual buses. BYD had been long time in battery production for consumer electronics before entering the NEV industry. Today, BYD is fully engaged in all sections of battery value chains, and supplies batteries for its own-branded electric cars and energy storage applications. These fast growing and innovative local firms have made Huizhou an emerging large-scale NEV battery production cluster in the Pearl River Delta and even in China.

2.4.3 Examples of technological learning

The above core competency is formed quickly thanks to the technological learning approaches adopted by Chinese battery firms. NEV is an emerging sector and needs much investment in developing technological innovations. What counts for battery products are their reliability and performance, not simply price. In terms of technological development, a battery-manufacturing firm has to be linked to technical partners that can provide solutions; on the other side, it shall cooperate with the supplier of raw materials, and then integrate hardware, raw materials, software systems and battery management systems into their own product - battery pack. Due to its electric-chemical nature, battery product innovation and process innovation are intertwined and often inseparable.

In Huizhou, NEV battery firms made substantial efforts on product and manufacturing process upgrading, with primary emphasis on battery product design and improvement. Normally they integrate battery management system (BMS) and sell battery packs to clients. E-POWER has a long-term cooperation with a team of Beijing Polytechnic University and is also actively developing upstream materials to replace imported materials. EVE increased drastically its production capacity and automatized the new large-scale assembly lines. It gained valuable battery production engineering and technical experience through expansion of manufacturing. E-POWER targeted niche markets such as public transportation by providing customized battery to hybrid electric buses and differentiated its Lithium battery from competitors with a unique design of heat dissipation system.

The most typical case of proactive technological learning accompanied by organizational learning is BYD. Before entering the NEV passenger car industry, BYD supplied lithium batteries and metallic accessories to branded consumer electronics firms, personal computer manufacturers, and mobile phone makers, such as Foxconn. Mobile phone accessories are in great demand and the marginal profit of mobile phone metal pieces has been quite high over many years, they contributed 40% of the firm’s total sales revenue. Based on its core technological competencies in batteries, electric control system, as well as the experiences in supplying metal parts, BYD entered directly the electric passenger car industry in 2003. BYD acquired a domestic-branded car firm - Qinchuan Automobile. There were few competitors in this new sector and the added value was higher than simply supplying parts.

In 2008, BYD purchased semiconductor-manufacturing company Ningbo Zhongwei for more than 200 million Yuan, and thereby acquired the competency to develop and produce electric engines. In 2015, electric vehicles accounted for 40% of BYD’s revenue. Besides electric vehicles, BYD also entered other emerging fields in the energy sector, such as solar panels, LED and related energy products, accounting for 20% of total revenue. An important motivation to enter the electric car business was to boost its battery production. BYD became a first mover in complete NEV assembly in the Chinese market. However, the firm still positions itself as an “energy corporation”, covering new energy vehicles, mobile energy storage and other segments based on using battery technology originated from consumer electronics lithium-ion battery. And in each segment, BYD continues its market upgrading by developing more technology products. For example, in electric vehicle segment, BYD produced electric power buses and trucks, and then launched projects of developing urban trams for public sectors.

Unlike Tesla, which in fact outsources the supply of batteries and gains the key manufacturing know how from its partners (Panasonic in particular), BYD owns its battery factories along the whole supply chain from cells to packs and supplies for its own car assembly. Recently the firm began to acquire upstream producers of battery raw materials. Learning from IT firms like Apple and its OEM Foxconn (Gereffi, Gary and Xinyi Wu, 2020), BYD adopts a highly vertically integrated organization and cheap labor-based mass production mode. It outsources very few components and materials, just supplementary materials like adhesives for batteries. This unique vertically integration approach facilitates BYD capturing the created value and possessing a leading position over the whole NEV value chain in China as well as in the world.

3. Political regulations of environmental and labor standards

3.1 Industrial policy context

The tightened subsidy policies (2.1.2) itself had an upgrading effect on quality and environmental standards. However, health and safety supervision and environmental regulations on lithium-ion batteries are relatively loose in the Chinese market. It is not that there are no industrial policies in this area, but that the results of policy implementation have large deviations. According to China Automotive Technology & Research Center, the total number of retired power batteries in China was about 200,000 tons in 2020, of which a large number flow into informal black-market channels such as small workshops, causing potential pollution risks to water, land resources, and human safety (Xinhua News 2021).

"Top-level design" of policies occurred only recently. In July 2021, China's major economic policy decision-making body, i.e., the National Development and Reform Commission published the "Circular Economy Development Plan during the 14th Five-Year Plan Period", highlighting the importance of NEV batteries recalls for the first time in a general national development plan. Four tasks were identified in the development plan: 1) to promote the establishment of standardized recycling service outlets through NEV manufacturing enterprises, battery recycling enterprises or their collaboration; 2) to promote the standardized cascade utilization of power batteries, and improve the technical capacity of residual energy detection, residual value evaluation, as well as restructuring and utilization; 3) to strengthen the application of complete sets of advanced equipment for the recycling and cascade utilization of power batteries; 4) to improve the standardization of power battery recycling.

The main administrative body for environmental and safety regulation of NEV batteries is the Ministry of Industry and Information Technology (MIIT). The ministry issued several directives on industrial standards regarding lithium-ion battery based on technological advices from the major enterprises in the industry. In addition, policy coordination is also emphasized by the regulatory authorities. The MIIT led to organize a technical committee to coordinate the management of cascade utilization of NEV batteries. In principle, the State Administration for Market Regulation mainly supervises the quality of battery products. The Ministry of Ecology and Environment is in charge of environmental pollution prevention and control in the production process of cascade utilization of batteries; the Ministry of Commerce carries out supervision on enterprises that dismantle scrapped NEV vehicles. In reality, the fragmented nature of Chinese administrative system places considerable difficulties on policy coordination.

3.2 Environmental and safety standards

In 2018, the MIIT, together with four other relevant ministries, issued the "Interim Regulations on the Management of the Recycling and Traceability of Electric Vehicle Power Batteries ('Regulations' hereafter)". It proposed to implement an extended producer responsibility system and full life cycle management of NEV batteries. In its Regulations, the MIIT stipulates that the vehicle manufacturing enterprises should be the main responsible parties for the recycling of batteries. In fact, there are not so many things that these vehicle manufacturers can do in terms of battery disassembly, recycling and reuse. Currently, battery manufacturing companies and third-party recycling companies are usually authorized to carry out battery recycling.

According to the Regulations, information collection is required for the entire process of power battery production, sales, use, scrapping, recycling, and re-use. A traceability management system and a national platform was proposed for enterprises to upload product information in the form of manufacturer code. This integrated traceability management system (www.evmam-tbrat.com) is based at the Beijing Institute of Technology. Three modules are included on the platform, which are vehicle management module, recycling management module, and local traceability supervision module.

In 2021, the MIIT issued the "Administrative Measures for the Cascade Utilization of Electric Vehicle Power Batteries". In order to utilize used NEV batteries, enterprises are encouraged to develop technologies applicable to areas such as base stations and energy storage productions. They are forbidden to apply the used batteries to products that cannot be further recycled and to areas that pose high environmental or safety risks. A number of pilot projects were established to encourage the cascade utilization of NEV batteries. Five companies were on the list of the first batch of enterprises that meet the industrial standards specified by the MIIT; twenty-two companies were in the second batch.

In March 2021, an online platform for retired battery trading was launched in Nanhai District of Foshan City in Guangdong. On this platform, traders are able to find a list of NEV power battery recycling service stations across China. They can also publish purchasing and selling information of retired batteries and seek power battery performance evaluation and laboratory testing services. According to the website, a total number of 16555 NEVs have been decommissioned and 28264 power batteries have retired as of November 2021 in China. Guangdong has the greatest number of decommissioned vehicles in the country, which amounts to 10175 NEVs and 11098 power batteries.[3]

3.3 Labor and occupational safety and health

General legal and regulatory framework has been established and applied to manage labor and working conditions in the NEV industry. Essentially, they are the "Labor Law", the "Safety Production Law", and the "Occupational Disease Prevention Law". The Chinese labor law stipulates that the minimum working age is 16 years old, forbidding the use of child labor and forced labor. Employment of workers shall not be discriminated against based on their ethnicity, race, gender, and religious beliefs. The labor standards apply to all types of workers, including contract workers in informal employment.

In terms of health and safety of workers, the production, operation, import and use of equipment or materials that may cause occupational hazards are banned by law. Employers shall establish occupational health surveillance files for workers and keep the records properly within the prescribed time limit.

If an organization or individual recruits minors between the age of 16 and18, or female workers during pregnancy or breastfeeding, they shall comply with the constrictions on types of work, working hours, labor intensity, and protective measures. The employers shall not arrange them to engage in excessively heavy, toxic, harmful labor or dangerous operations that may endanger their physical and mental health.

[3] https://dianchizhijia.com/home/retireBattery

4. Production models and labor regimes

The changes in value chains have a potentially huge impact on work and employment in the car industry, which have hardly been researched yet. Early estimates and beginning job reductions at global carmakers indicated that substantially fewer workers will be needed for NEV manufacturing and that the traditional mechanical skills of car workers and engineers will be devalued (HBS 2012). The impact from changing value chains and relocation are not included in most studies, however. As the electronics industry demonstrated, the revolutions in technologies and business models in the 1990s initiated a massive transformation of manufacturing. In its course, most traditional computer and telecommunications production was closed down or sold to contract manufacturers and relocated to emerging economies (Lüthje e.a. 2013a).

4.1 Foxconnization of car manufacturing?

In the Chinese car industry, massive state-of-the art production bases have been developed during the recent two decades. However, job losses among core global carmakers and their home regions have been less severe than in comparable industry, e.g. electronics. Most carmakers duplicated their production networks rather than using China as a location for low-cost export production. However, this may change in the course of the current transformation towards NEV.

As we have explained already this implies a break in the existing competitive structure and production models in the Chinese car industry - between the incumbent joint ventures with relatively upscale wages and working conditions on the one side, and their competitors from independent carmakers and the IT industry on the other. The latter mainly rely on low-wage manufacturing workforces with high proportions of rural migrant workers.

The sectoral transformation of China's car industry traced in the preceding sections also involves a complex restructuring and recombination of the existing regimes of production (Lüthje e.a., 2013b).

In the **joint ventures** of leading OEMs the globalized model of state-capitalist regulation is aligned with regimes of production that combine the practices of transnational automakers with the party-based management systems of their Chinese partners. This has resulted in the characteristic twin structure of Western and East Asian corporate lean management and state-bureaucratic practices on the shop floor (Lüthje and Tian, 2015). Today, the core factories of the JVs suffer from increased cost competition and slower market growth. Workforce reductions and plant closures have been seen in major centers of car manufacturing in China.

Most carmakers have started to incorporate manufacturing of electric or hybrid vehicles into their existing production lines, adding new flexibility requirements for factory organization and workers. Increased pressures have led to workers' dissatisfaction over deterioration of pay, benefits and employment prospects, especially for temporary workers. In one case, FAW-VW in Changchun, this caused in 2017 a major labor conflict with temporary workers over principles of equal pay for equal work (China Labour Bulletin 2017).

Independent carmakers, NEV and battery producers: Most of these companies rely on vertically integrated production with high flexibility and workforces with wages substantially lower than in the joint ventures. The rule of thumb among industry experts is about 9 US-dollars as a standard hourly wage at the top joint ventures compared with 4-4.50 dollars at independent carmakers such as Geely and BYD (Automotive News China, 2017). The lower wage scale is especially prevalent among companies with a background in the electronics industry such as BYD and most battery makers.

Their regimes of production represent a high-performance type of labor relations, which has been adapted from Korean, Taiwanese and U.S. models. Wages and employment conditions are fairly decent, but the system is highly incentive-based. Skilled employees can achieve considerable extra income and promotions, but work organization is based on relatively low base wages and salaries, usually less than 50% of regular monthly incomes. Production workers, many of them migrants, are forced to work overtime to achieve a living income (Lüthje e.a., 2013b). The production systems of these companies are very flexible, but rely on a core of relatively experienced skilled or semi-skilled workers. One of the leading firms of this kind maintains its operations in two large industrial parks in South China, one employing 20.000-30.000 and the other one over 70.000 workers (2017/18 field research and interview data, and IPRD 2018).

Electronics contract manufacturers in China are notorious for their poor working conditions and low wages. Their very large factories, many of them with 100.000 or more workers represent a regime of flexible mass production that draws its unique characteristics from China's system of internal labor migration (Lüthje e.a. 2013b). It is based on large-scale employment of rural migrant workers in coastal provinces or big-city inland locations with base wages at the local legal minimum wage and massive overtime work, often beyond legal limits. Work is extremely segmented and deskilled, designed to facilitate mass recruitment and lay-offs according to market conditions. Workers are mostly housed in dormitories, often with harsh living conditions. With the increasing role of EMS contract manufacturers in NEV and digital car production, such working conditions are expected to penetrate supply chains. Trade unionists in developed countries, therefore, speak of the "Foxconnization of car manufacturing".

Car suppliers have diverse regimes of production, reflecting the segmented structure of the industry and their positions in the supply chain. First-tier multinational car suppliers have high-performance type of production regimes, while those in joint ventures with state-owned Chinese carmakers have state-bureaucratic forms (Lüthje e.a., 2013b). The car supply industry in China generally works at wages much lower than in the core joint ventures, including first-tier multinationals such as Bosch or Denso. The lower levels of the car supply sector in China are typically traditional low-wage industries, comparable to the flexible-mass-production regimes in the IT industry or to the "classical" low-wage environment of labor-intensive small and medium enterprises.

A recent study of the car supply sector in South China indicated that the shift to NEV car manufacturing and automation have not yet caused major restructuring among car suppliers at the middle and lower tiers, since most of the car manufacturers in the region still focus on traditional car technologies (Yang e.a., 2019). Automation, however, does have potentially heavy impact at the low ends of the supply chain. Recent studies of metal-related manufacturing industries in Guangdong province found that relatively simple forms of automation (mostly with Chinese-branded low-cost robots) lead to massive replacement of manual labor, often affecting the most experienced workers in physically challenging labor processes such as machining of metal or polishing of stainless parts (Huang and Sharif, 2017).

4.2 Work processes in LIB manufacturing: observations from factory visits

The work process in LIB manufacturing has not been studied systematically yet. It is very different, however, from the manufacturing of traditional lead-acid batteries, which had been notorious for severe toxic health hazards for workers, especially in developing countries including China. The manufacturing of Li-ion batteries is highly automated in most core processes, and includes printed circuit board and mechanical assembly as known from the electronics industry. In the absence of systematic studies, we provide a first description of manufacturing processes along the industrial chain from factories in the Pearl-River Greater Bay Area (GBA) that we visited between 2017 and 2019.

In general, LIB manufacturing is highly automated and usually does not require large factory workforces as in traditional car or electronics production. According to figures published by the companies (see Appendix 1), China's largest battery maker, CATL, has a total workforce of roughly 20.000, distributed over 9 factories (including the newly established one in Erfurt, Germany) and R&D facilities, mostly located at its headquarter in Ningde, Fujian province. The workforces of other battery makers appear to be much smaller.

Some of the leading battery makers concentrate their production in large industrial campuses that include up- and downstream production processes like cell or electronics assembly, or the manufacturing of electric vehicles or electronics products. BYD has most of its production in three large campuses in Shenzhen and Huizhou, each of which with several ten thousand employees. Battery factories are located within these industrial parks, which also include R&D facilities, logistics and large dormitories and apartment buidlings for workers.

Similarly, the joint-venture battery factory of CATL and Guangzhou Automotive Corporation (GAC) is located in GAC's large new energy car industrial park in the Panyu district of Guangzhou City. The presumably largest battery factory in the GBA manufacturer is located in Huizhou and has been developed as an integrated industrial park in a rural greenfield locations. The workforce consists overwhelmingly of migrant workers housed in dormitories.

Along the production and industry segments identified above, the following profile of the work process can be drawn (this does not include refining, production of basic materials, and recycling, since we did not have the opportunity to visit relevant facilities).

Production of anodes and cathodes is an industrial manufacturing process that includes metallization, metal forming and die-casting. It is performed in small-to-medium sized factories with smelter ovens and similar equipment. It includes heavy physical work with high impact from noise, fumes and high temperatures.

Production of battery cells, the core process**,** is highly automated and occurs in large cleanroom-like facilities. It involves the preparation and processing of micro-thin copper foils, from which the battery cells are made, several stages of metallization and galvanization, and the final rolling of the material into small cylindric battery cells. The quality, calibration and maintenance of the equipment is crucial for the production process, which must maintain highly uniform quality of millions of battery cells. Most of the equipment is from first-tier providers from Japan and South Korea. Due to the highly automated character of the process, the workforce inside the cleanrooms is very small, mostly skilled or semi-skilled equipment operators and maintenance workers. Outside of the cleanrooms, most work is in logistics and warehousing.

Packaging and assembly of batteries occurs in facilities of different sizes according to production volumes and product characteristics. Cells are inserted into metal casings and frames, usually by medium-skilled assembly workers with some experience. In larger facilities, this is done on assembly lines with some automation, smaller facilities mostly use hand assembly. In cooperation projects between carmakers and large battery providers, parts of the battery assembly may also be located in or near car plants.

Electronics assembly (battery management systems) consists of the generic work processes of electronics manufacturing, i.e. assembly of printed circuit boards (usually with program-controlled SMT and soldering equipment), hand assembly of certain non-standardized parts and enclosures, and final testing. According to volumes and product characteristics, this work is performed in facilities of different sizes, some of them integrated in electronics factories with varieties of other products.

Production of battery frames and casings occurs in specialized factories of different sizes and involves standard processes of metal manufacturing such as cutting, drilling, welding etc. Production is becoming more and more automated, leading companies in the GBA use imported high-precision equipment and robots to improve production quality and save labor costs.

Final assembly and configuration for car frames mostly occurs at the facilities of the carmakers that use externally produced battery cells. The work organization differs according to the products and the production models of the various carmakers. As has been explained above, the division of labor between carmakers and battery providers are still relatively unstable. The largest car factory in South China, a Sino-European joint venture, has built a battery assembly plant on its factory campus. This plant configures the batteries for the multinational's traditional car platform and models. This process is relatively labor intensive, because platforms for combustion-engine vehicles are not suited to receive large LIB assemblies. With the transition to a specific platform for electric vehicles, standardization and modularization of this process is expected with potentially fewer workers. The testing of the batteries requires extensive safety checks. Workers have to acquire special training and certification, which the company provides through its highly developed internal vocational training system.

In general, the work process in LIB manufacturing is relatively differentiated in its various stages and segments, but its basic characteristics are similar to industrial production known from in the metal and electronics sectors. Much of the existing knowledge on practices of decent work, workforce training and occupational safety and health can be applied to this field. For the core process of battery cell manufacturing, there exist no viable studies on the chemical and toxic risks for workers. The existing Chinese and international literature on health hazards in battery manufacturing only mostly deals with traditional lead-acid batteries.

According to our observations, working conditions and workforce in the battery industry resembles those of other manufacturing industries such as electronics or automotive supply. The majority of workers are lower- to medium-skilled who are paid according to the general local standard wages in the GBA (around 5000-6000 RMB per month for lower skilled and 6000-8000 medium to higher-skilled assembly workers and equipment operators). Skilled maintenance workers are relatively few, since maintenance and calibration of equipment is mostly performed by engineers with college degrees.

As in the GBA in general, most workers including the higher-skilled ones and engineers have a migrant background from rural areas of Guangdong or other provinces. Production workers are housed in dormitories, either on company premises or in rental facilities in industrial areas. Higher skilled workers live in apartments provided by the companies or in private housing areas. Under the existing rules and regulations, migrant workers have no long-term residency in the cities of employment and have only limited access to social services, schools and government subsidies for housing etc. Therefore, the turnover among the local industrial workforce remains high, also among higher-skilled employees.

4.3 Worker rights and trade unions

In the broader context of the restructuring of the Chinese car industry, the work regimes in battery manufacturing can be considered as one element of the "Foxconnization" of car manufacturing described above. Battery production and the related areas of electronics manufacturing have adopted indigenous Chinese regimes of high-performance production or flexible mass production as known from electronics contract manufacturers. Only in the final assembly and configuration facilities that are connected to core carmakers and their joint ventures it can be assumed that working conditions and pay are at the level of established first-tier car companies.

From this perspective, the battery industry reflects the divisions along the production chains of the automotive industry in China, which have been analyzed in the literature quoted in this report. Official trade unions have an established presence in state-owned carmakers and their joint ventures, but they do not play a strong role in setting the standards of wages and working hours. Collective contracts and bargaining procedures only exist at company level, there are no industry-wide labor contracts or wage standards. However, the wages and benefits at state-owned carmakers are comparatively high, auto workers are among the highest paid industrial workers in China. In addition, the state-owned carmakers have comprehensive vocational training systems and internal labor markets. Wages and wage classifications are linked to workers' achievements in education and training.

Under the labor regimes prevalent among private carmakers and electronics firms, wages and benefits for production workers are much lower. Trade unions exist in most of the larger companies, but their position is still weaker than in SOE and joint ventures, where the trade union normally is integrated into the management structure. As we have mentioned already, under the rapid expansion of the NEV sector in general and battery manufacturing in particular, these conditions may rapidly become the 'new normal' in automotive manufacturing in China.

In general, the employment in these companies represents lower- to middle-standards of work and pay in China. Working conditions in foreign-invested enterprises and joint ventures are significantly higher, these companies are seen as preferred employers among Chinese workers. On the other hand, conditions at Chinese private companies in the car sector such as BYD, Geely or bigger battery makers are significantly better than in labor-intensive smaller and medium enterprises, which represent the lower end of supply chains of the automotive and electronics industries.

Major labor conflicts or publicly known violations of worker rights in the NEV-battery industry could not be detected in the course our research. In the respective locations in the GBA and other areas in China, several cases of severe poisoning of workers in the production of traditional lead batteries have become known between 2005 and 2015. There are no such reports about LIB facilities or related electronics factories. We cannot say much about working conditions and wages in the mining, materials processing and recycling segments. Since most of the facilities are located in rural mining districts in northern and central China, one may assume similar conditions as in coal and other mining industries.

5. Conclusion and Recommendations

This report analyzed major structural changes and trends in the emerging NEV battery industry in China, in order to understand the changes in the supply chains of global carmakers and challenges for promoting social and environmental sustainability in this sector. In the concluding chapter, the major implications of our analysis with regard to key strategic questions from the perspective of international trade unions will be summarized. Our recommendations are based on the view that in a rapidly developing global industry such as NEV battery production, "decoupling" from or vs. China is impossible, and global governance around environmental sustainability, decent working conditions and shared prosperity is mandatory.

5.1 Industry structure and global supply chains

As we explained in the first section of this report, the automotive sector is undergoing a massive transformation that historically can be compared to the break-up of Fordist and Neo-Fordist production models and the subsequent globalization of major manufacturing industries in the 1980s and 1990s, electronics in particular. Vertical disintegration and re-integration is at the core of this process. On the one hand, the existing production systems of global carmakers and their hierarchical supplier pyramids (commonly known as the "Toyota model") may gradually lose their core role in the automotive sector. New sources of production know-how are emerging, which is no longer exclusively controlled by traditional car makers. NEV batteries are a key element in this transformation.

Compared to the 1990s, the conditions of what we call "globalization" have changed considerably. Emerging economies have not only developed as low-cost production bases and "extended work benches". Rather, they have accumulated substantial technological and production know-how at various stages and become important players in global innovation. In the NEV and battery sector, China is the global lead market, the major producer and a key innovator. Global supply chain development, therefore, no longer is a top-down process, controlled by the leading global brand-name companies in industrialized countries, but multidimensional in the sense of distributed centers of innovation and industrial players controlling different segments. The global carmakers are no longer the undisputed leaders of industrial development in the auto sector.

China caught the opportunities of impeding disruptive transformation and gained a leading position as a first mover in NEV battery making. This development was based on a large sector of battery suppliers for consumer electronics, computers and mobile phones. China now has a complete LIB value chain for NEV, from upstream materials production to midstream manufacturing of cells, modules, BMS, and packaging, as well as downstream applications in mobility and various other fields, such as grid storage, lighting, solar energy, and movable storage. Within the automotive sector, Chinese battery producers are becoming important players as providers of core components, reaching out into other battery technologies such as fuel cells.

In this report, we have explained in detail the factors of this development, including China's national industrial policy, the country's market size, continuous improvement of legislation and regulation, the existence of vast natural resources, and the strategies of key industrial actors. Most importantly, of course, industrialized countries have privileged and protected the traditional car industry and delayed the development of NEV until very recently. Global automakers benefited from the massive growth of the traditional car market in China between 2000 and 2017, but ignored the massive need for innovation deriving from climate change and the ecological problems of car traffic, especially in large urban environments.

The dominant strategy of Chinese firms can be described as **specialized vertical integration** across the industrial chain, including LIB cell production, mining and refining, cell materials and components, electronics assembly, packaging, final assembly of NEV and building of charging stations. Major firms expand and integrate their activities into various stages of the production system, but vertical integration remains within the battery value chain and around the specialized field of battery or electricity storage.

With regard to global production networks in the NEV battery industry and China's role within it, this development has distinct strategic consequences:

- Vertical integration enables major Chinese players to grow fast and maintain leading technological positions based on long-term strategic investment. Economies of scale are crucial for mass production of NEV batteries, as only large players with extensive resources of capital and technology will be able to survive.
- The rapid integration of battery making with mining and materials production ("upstream"), on the one hand, and battery recycling ("downstream"), on the other, is becoming a key factor of future industry development; it further supports China's leading role in global supply chains.
- Specialized vertical integration can be seen as a distinctive Chinese model of firm organization; for some leading firms, battery production has become the core of corporate organization, as represented by BYD's concept of a vertically integrated new energy company. Whether such models can play a globally leading role in the future remains to be seen. However, specialized vertical integration should definitely be considered as a model for industrial-policy making in developed countries.
- The ongoing rapid integration between Chinese battery and NEV producers, which are mostly privately owned, and the mining and refining sector, which is dominated by large state-owned enterprises, can also be seen as a recombination of market- and state-led development that may further support China's dominant global position in the battery sector.
- Regional clustering within China is an important element of specialized vertical integration. It promotes opportunities of flexible specialization for small- and medium-sized firms along the production chain, complementary to the globalization of major battery makers. Clustering also can be considered a model for industrial policy in other world regions.
- The rapid expansion of the NEV battery sector along with massive speculative investment globally and in China is propelling overcapacity in LIB production. This is represented by low rates of capacity utilization and price volatility in the battery industry in China. This trend is complemented by the global expansion of battery manufacturing and accelerated by industrial policies to provide "supply chain security" in the EU and the U.S.

5.2 Environmental and social sustainability

This report described China's economic and social framework to ensure the environmental and social sustainability of battery manufacturing. Given the systemic weakness of trade unions, business associations and civil society organizations, environmental and labor standards are mostly secured by laws and regulations provided by the state at various levels. China has established a comprehensive framework of environmental and labor legislation, which is comparable to industrialized countries or more advanced in some aspects. However, the enforcement of national laws and regulations through local governments differs considerably, giving room to loopholes and violations of existing laws.

In the environmental field, China has established a comprehensive framework of laws and regulations connected to national and regional industrial policies to promote NEV and "green" mobility. As we have explained, the industrial policies to upgrade NEV manufacturing have important effects of upgrading for battery manufacturing, both with regard to product safety and recycling. China's current effort to build a comprehensive system of NEV-battery recycling are ambitious and advanced compared to similar efforts in developed industrial countries. One reason is that the unexplored negative environmental consequences of NEV-based mobility, such as rising electricity consumption, shortage of raw materials and growing electronic waste, have become more visible in China than elsewhere.

Reports about these and related problems have been rare and the potential environmental problems of NEV mass production are hardly present in Chinese mainstream media. However, there remain a number of open questions, which should also be raised in due diligence procedures with major carmakers.

- The environmental impact of LIB manufacturing has not been systematically studied in major industrial countries, including China. Given the size and scope of the industry in China, a systematic review of environmental impact studies of battery plant location could give important insights on this field.
- The same can be said for recycling facilities and the environmental impact of materials mining and refining. Since these industry segments are mostly located in rural and less developed regions in China, the impact on rural and environmental development should be studied, also in other developing countries.
- Unregulated recycling facilities have been a problem in China. The government recently has promoted efforts to eliminate unregulated recycling and to promote recycling platforms. The question has to be raised how effective these policies are and whether battery makers and recycling still use unregulated recycling facilities. On the other hand, new initiatives in this field, such as the online trading platforms for used batteries, should be studied.

In the field of labor relations, the "Foxconnization" of car manufacturing through the rapidly growing NEV segment brings lower wage and employment standards to the Chinese automotive industry, which has been dominated by state-owned enterprises and joint ventures. Whether this development will induce a general trend to lower wages in core automotive manufacturing in China, or whether there the existing segmentation of employment conditions between some first-tier carmakers and the lower tiers of the supplier networks will be increased, remains to be seen. Certainly, this will depend on the degree to which official trade unions and government labor bureaus will be involved at the local level, and whether existing labor laws and standard are properly implemented.

Consequences on global supply chains may be different from the electronics industry, since the emerging NEV sector does not yet have a clear division of labor between technology-defining brand-name firms (such as Apple, Dell or Huawei) and manufacturers (such as Foxconn). In addition, the motives to relocate factories and build global production network are not only in lowering labor costs, rather than strategic considerations concerning market proximity, co-operation and co-innovation with end users, global carmakers in particular. Electronics contract manufacturers themselves are becoming important players in production networks for NEV with substantial technological resources. Some of them have already established joint ventures with global carmakers in China, such as Foxconn with Stellantis.

The open questions to understand the production regimes of major battery firms and to be studied in future due-diligence procedures of carmakers are mostly related to the general framework of labor relations in China.

- Do companies comply with existing labor laws and health-safety regulations?
- Are those regulations implemented properly at the local level?
- Do companies pay living wages and decent benefits according to existing laws and regulations?
- Do companies accept trade unions and collective bargaining regulations, such as the collective bargaining guideline in Guangdong province?
- Do the wage systems of companies relate to workers' skill levels and do they provide incentives and remunerations for learning and skill development?
- Do the companies provide quality vocational training, and how is skill development at company level related to vocational education in public schools and institutions?
- Working conditions and OSH in battery cell production: given the scarce knowledge of health hazards in LIB manufacturing, there remains a wide array of open questions, which should be studied systematically. Studies should also be based on data from the

manufacturing of Li-ion batteries for consumer electronics and IT products, which has existed for several decades.

- Working conditions in mines, refining and smelter facilities. Little is known about the situation in lithium and metal mining facilities, but it can be assumed that there exist similar issues of OSH, wages and working conditions as in coal and other sectors of China's large mining industry. Those industries have been relatively well studied and can serve as reference.

5.3 Policy recommendations

a) Decent work in battery manufacturing is a key issue to make the new-energy vehicle industry sustainable and to ensure social standards in the green transformation of the automotive sector and the global economy. Trade unions are key actors in this field and should develop their activities based on systematic analysis of supply chains and industry structures. Crucial lessons can be learned from previous transformations of manufacturing industries, electronics in particular. Industrial unions should develop proactive policies to secure social and environmental standards in global supply chains and to support industrial policies to reshape the automotive sector along the lines of shared prosperity between emerging and industrialized economies.

b) Industrial unions should develop **industry-wide perspectives** of securing labor, environmental and safety standards in battery manufacturing. As the development in China shows, NEV-battery production is emerging as a diversified industrial sector with different types of firms and specialization and with a high degree of local clustering. Such an environment provides the conditions for industry-wide organizing, collective bargaining, and industrial policies. However, union strategies for the automotive sector must go beyond securing the traditional interests of core carmakers and their workers. It must rather define new strategic goals that include workers in the battery industry and along the global supply chain of mining, refining and materials production as well as the strategically important recycling sector.

c) Industrial unions should promote industrial policies that support **diversity** within the battery sector, rather than engaging in a global technology race based on the creation of mega factories with large amounts of government subsidies. The current policies in Europe and the U.S. to catch up with battery cell producers from China, Japan and Korea support such a technology race in the name of "supply chain security". The experiences from local industry clusters in China offer strategic perspectives of diversified development that may also be conducive to the conditions of industrialized countries, especially to small and medium-sized enterprises in the electronics and automotive supply sectors. Such industrial policies can also help to counterbalance an emerging oligopoly of global battery makers in conjunction with large carmakers.

d) Industrial unions should support open markets together with strong **multilateral social and environmental standards** for battery manufacturing. Given the global structure of supply chains and the position of China and other emerging economies in innovation, "decoupling" and protection of national or regional markets is not possible and not practical for workers and trade unions. This is also true for the mining and materials sector, which needs viable global standards and enforcement within multilateral institutions and agreements. Transnational agreements on trade, investment, and technology should include such standards, international trade unions should actively engage in relevant negotiations. The investment agreement currently under negotiation between the EU and China, for example, should not only contain protections for investors, but also for workers and communities.

e) The representation of workers and trade unions in the Chinese LIB apparently is weak. The labor standards in the emerging battery sector and its relevant locations have been shaped by the electronics industry, which mostly employs migrant workers and provides low or very low wages. However, in global perspective this situation seems to represent the norm, rather than an exception. **Organizing** the fast-growing NEV battery industry, obviously, has to be a top priority for industrial unions. As known, Chinese trade unions do not engage in such activities and labor relations are mostly dominated by the state. However, industrial unions could promote the organization of employees of newly built battery factories of major producers from China and South Korea in North America and Europe. Recent experiences from companies with Chinese ownership in Europe show that many Chinese multinationals accept local labor laws and standards, including works councils and trade unions.

f) Industrial unions should seek **cooperation with Chinese trade unions** and experts from government, companies and relevant organizations. The joint ventures of international carmakers can provide an important platform, some of which have developed regular communication between trade unions at company level. The facilities of Chinese battery makers in Europe could create similar channels in the future. Given the scarcity of information on key questions of industrial, environmental and social development of battery manufacturing, we need further studies of production models, supply chains and labor process. Industrial unions should initiate **health and safety studies** on core processes of battery manufacturing and establish communication with Chinese trade unions and experts on questions of working conditions and work safety. The situation in the **mining and materials secto**r requires special attention, since little is known about working conditions in relevant facilities in China and in developing countries in Africa and South East Asia.

g) Supply-chain monitoring and due diligence by stakeholders at multinational carmakers can play an important role to raise awareness and promote communication. In China, this would require communication with and through the joint ventures of the respective companies. The joint venture partners and their union representatives should be actively involved. Communication should be built on extensive knowledge of Chinese laws, regulation and practices. Precise questions have to be developed regarding the locations, health and safety standards, union representation and the local implementation of relevant labor laws and regulations.

54 bis, route des Acacias
CH 1227 Geneva
Switzerland

Tel: +41 (0)22 308 50 50
info@industriall-union.org
www.industriall-union.org

President: Jörg Hofmann
General Secretary: Atle Høie

Appendix 1. List of Major Companies

Companies of LIB cell, module, pack and BMS manufacturing

Company Name	Location of Headquarter	Location of Factories (China)	Year of Establishment	Number of Employees	Company Website
Contemporary Amperex Technology Co. Ltd. (CATL)	Ningde, Fujian	Xining,Qinghai; Changzhou, Jiangsu; Yibin, Sichuan; Zhaoqing, Guangdong; Yichun, Jiangxi; Ningde, Fujian; Xiamen, Fujian; Shanghai; Erfurt, Germany	2011	19732	www.catl.com
BYD Company Limited	Shenzhen, Guangdong	Xining, Qinghai; Shenzhen, Guangdong; Chongqing; Changchun, Jilin; Changsha, Hunan	1998		www.byd.com
Gotion High-Tech	Hefei, Anhui	Hefei, Anhui; Lujiang, Jiangxi; Nanjing, Jiangsu; Qingdao, Shandong; Tangshan, Hebei; Nantong, Jiangsu; Liuzhou, Guangxi	2006	2608	www.gotion.com.cn
Lishen	Tianjin	Qingdao, Shandong; Suzhou, Jiangsu; Wuhan, Hubei; Mianyang, Sichuan	1997	2631	www.lishen.com.cn
EVE	Huizhou, Guangdong	Huizhou, Guangdong; Jinmen, Hubei;	2001		http://www.evebattery.com

Farasis	Ganzhou, Jiangxi	Zhenjiang, Jiangsu; Wuhu, Anhui; Ganzhou, Jiangxi	2009		http://www.farasis.com
BAK	Shenzhen, Guangdong	Shenzhen, Guangdong; Zhengzhou, Henan; Chengdu, Sichuan;	2001		http://www.bak.com.cn
Sunwoda	Shenzhen, Guangdong	Huizhou, Guangdong	2014		www.sunwoda-evb.com
LG	Suwon, South Korea	Nanjing, Jiangsu	1947		https://www.lg.com
Panasonic	Osaka, Japan	Shenyang, Liaoning	1918		https://www.panasonic.com
SK	Seoul, South Korea	Huizhou, Guangdong; Yancheng, Jiangsu; Changzhou, Jiangsu	1953		http://eng.skinnovation.com
Samsung	Suwon	Xi’an, Shaanxi	1938		https://www.samsung.com

Companies of raw material mining and refining & LIB materials producing

Company Name	Location of Headquarter	Location of Mines/Factories	Year of Establishment	Number of Employees	Company Website
Minmetals (State-owned)	Beijing	Mangnai, Qinghai;	1982		www.minmetals.com.cn
Jinchuan (State-owned)	Jinchang, Gansu	Jinchang, Gansu	2001	27102	www.jnmc.com
Huayou	Jiaxing, Zhejiang	Jiaxing, Zhejiang; Tianjin; Tongling, Anhui, Hohhot, Inner Mongolia	2002		www.huayou.com
BYD Salt Lake Resources Co. Ltd.	Golmud, Qinghai	Qarhan Yanhu, Qinghai	2017		
Corun New Energy Co.Ltd.	Changsha, Hunan	Foshan, Guangdong; Changsha, Hunan	1998		www.corun.com
GHTECH	Shantou, Guangdong	Shantou, Guangdong	1980	716	
Tinci High-tech Materials Co.Ltd.	Guangzhou, Guangdong	Jiujiang, Jiangxi; Tianjin;	2000	529	www.tinci.com
Shanshan Technology	Shanghai	Dongguan, Guangdong; Baotou, Inner Mongolia; Changsha, Hunan; Quzhou, Zhejiang	1999		www.shanshantech.com

Appendix 2. Production, research, and market capabilities of battery firms in Huizhou

<table>
<tr><th></th><th>Mass production and advanced manufacturing capabilities</th><th>Technology and R&D capabilities</th><th>Customer and market capabilities</th><th>Strategic intent of development</th></tr>
<tr><td>Battery NM</td><td>-Reached mass-production and are expanding production capacity;
-Automated production lines, import of key equipment.</td><td>- Developed a silicon carbon anode material;
- The R&D base is headquartered in Shenzhen;
- Development of comprehensive lithium battery technology solutions (material application)</td><td>- Domestic mainstream customers;
- Develop materials together with customers;
- Traditional cathode and anode materials markets are saturated</td><td>From the production of cathode or anode materials to developing and manufacturing all materials, including cathode and anode materials, electrolytes, separators, and binders.</td></tr>
<tr><td>BYD</td><td rowspan="7">-Mass production and large-scale expansion of production capacity (totally 12.1 GWh/year)
-Semi-automatic, fully automated, and intelligent manufacturing lines are used according to different products. But less automatic production line for pouch packs
-The front-end equipment is mostly imported, and the battery pack assembly line and logistics line at the back end are developed by firms in-house.</td><td>-"Blade" battery design
- Research is mainly to extend battery life and increase capacity density</td><td rowspan="7">- Supply to the producers for battery modules and battery packs assembly, some of them are local producers
- Domestic mainstream customers, and international mainstream customers (OEM);
- Emphasize a rapid response to customer needs;
- Equipped with specialized professional after-sales service;
- The impact of the policy on the market demand is relatively big, felt by pressure on cost killing from clients (OEM)</td><td rowspan="3">- Integrating into the production of the complete EV battery system, based on the core technology expertise in cell production
- Reducing e costs through capacity expansion to increase market share;
- Development towards integration of whole EV assembly and production</td></tr>
<tr><td>EVE Lithium Energy</td><td>Routine development of cell design</td></tr>
<tr><td>Sunwoda</td><td>Battery system design optimization</td></tr>
<tr><td>E-Power Energy</td><td>-Circuit system design, using active liquid cooling technology for battery systems
-R&D associated with battery material research</td><td>Focusing on electric bus system and pouch battery design</td></tr>
<tr><td>Haopeng Technology</td><td rowspan="2">There is a gap between the overall technological level with Japanese and Korean companies</td><td rowspan="2">Staying in the market of BMS and pack assembly</td></tr>
<tr><td>Yineng Electronics</td></tr>
<tr><td>Desay Blue Micro New Energy</td><td>Iterative development of software systems, multiple sets of BMS</td><td>Niche market specialist</td></tr>
</table>

	Mass production and advanced manufacturing capabilities	Technology and R&D capabilities	Customer and market capabilities	Strategic intent of development
Yinghe Technology	-Has reached mass-production and is expanding production capacity; -The overall level of automation of equipment production is not very high. -Non-standard equipment products must be assembled by hand. -Precision parts processing with automation	- The only firm manufacturing intelligent production line solution for lithium battery production (turnkey project); - Developed industry-specific manufacturing execution system (MES); - Develop "digital factory“ concept	- Domestic mainstream customers; - Products are customized for customers; - Provide a lot of training support for customers, similar to robot manufacturers	Integrate equipment manufacturing for whole process of lithium battery production, from front-end electrode production, middle-stage cell assembly, to rear-end cell finishing, and promote intelligent manufacturing system
Kedali Precision	-Plans to produce 30 million sets per year; it has reached mass production and is expanding its production capacity; -Main equipment is imported. -Equipped with automated production line. -Pre-purchase of equipment suppliers' several years of production capacity	- Take use of experience in the mold industry since many years to carry out product process innovation; - Develop precision components for intelligent vehicle control systems	- Serves domestic mainstream customers; - The national market share is 50%, and the global market share is 20%; - Keep up with the needs of mainstream car (OEM) companies	Niche strategy to become a first tier supplier of lithium battery precision structural parts and new energy automotive parts assembly

References

Alochet, M. (2020). Are Chinese regulations shaping the global deployment of the EVs industry? Paper presented to Gerpisa colloquium 2020.

Berger, S. (2013). *Making in America: From Innovation to Market*, Cambridge: MIT Press.

Conner, K. (1991). "A Historical Comparison of Resource-Based Theory and Five Schools of Thought within Industrial Organization Economics: Do We Have a New Theory of the Firm?", *Journal of Management*, vol.17, pp.121-154.

Dongfang IC (2019). "Ningde Shidai de quanqiuhua kuozhang, goujian dianchi chanye de da geju (CATL's global expansion, creating the battery industry's big pattern)", *Yan Zhi qiche jianwen (Yan Zhi Automobile Insight). Market Report.* Author: Beidu Nangui. WeChat Offical Site http://mp.weixin.qq.com/s/SJ4RJqUrl

Financial Times (2017, October 15). Geely and Volvo jointly develop components. *Financial Times*.

Financial Times (2019a, July 10). China's car market set for second year of falling sales. *Financial Times*.

Financial Times (2019b, July 12). Ford and Volkswagen to share costs on electric and self-driving cars. *Financial Times*.

Financial Times (2020, October 17). Foxconn accelerates electric vehicle drive with new tech platform. *Financial Times*.

Financial Times (2021, January 8). Foxconn ramps up EVs push via deal with Chinese start-up. *Financial Times*.

Fraunhofer ISI (2016). Energiespeicher Monitoring 2016: Deutschland auf dem Weg zum Leitmarkt und Leitanbieter? *Frauenhofer ISI Research Report*. Karlsruhe: Fraunhofer-Institut für System- und Innovationsforschung ISI.

Gao Gong Industry Institute. (2018). Top 10 Chinese Lithium-ion Battery Makers in 2018. GGII, January 10, 2019. https://www.gg-lb.com/asdisp2-65b095fb-35935-.html, retrieved on 4 November 2020.

Gao Gong Industry Institute. (2019). Top 10 Chinese Lithium-ion Battery Makers in 2019. GGII, March 10, 2020. https://www.gg-lb.com/art-39878.html, retrieved on 4 November 2020.

Gao Gong Industry Institute. (2021). Top 15 Chinese Lithium-ion Battery Makers in 2020. GGII, February 26, 2021. https://www.gg-lb.com/art-42311.html, retrieved on 17 August 2021.

Gereffi, G., & Korzeniewiczs, M. (Eds.) (1994). *Commodity Chains and Global Capitalism*. London and Westport Ct.: Praeger.

Hans Böckler Stiftung (HBS) (2012). *Elektromobilität und Beschäftigung. Wirkungen der Elektrifizierung des Antriebsstrangs auf Beschäftigung und Standortumgebung (ELAB)*. Düsseldorf: Hans Böckler Stiftung.

Huang, Y, & Sharif, N. (2017). From 'Labour Dividend' to 'Robot Dividend': Technological Change and Workers' Power in South China. *Agrarian South: Journal of Political Economy*, *6*(1), 53–78.

Huth, C., Wittek, K. and Spengler, T.S. (2013). "OEM strategies for vertical integration in the battery value chain", *International Journal of Automotive Technology and Management,* vol. 13, no. 1, pp. 75-92.

International Council on Clean Transportation (ICCT). (2018). China's New Energy Vehicle mandate policy (final rule) [WWW Document]. International Council on Clean Transportation. https://www.theicct.org/publications/china-nev-mandate-final-policy-update-20180111, retrieved on 28 October, 2020.

International Energy Agency (IEA). (2019). Global EV Outlook 2019 - Scaling up the transition to electric mobility, IEA Technology report, May 2019. https://www.iea.org/reports/global-ev-outlook-2019, retrieved on 4 November 2020.

IPRD (Institute for Reform and Development of the Pearl River Delta) (2018). Huizhou shi chanye he chengshi fazhan yanjiu baogao (Industrial and Urban Development in Huizhou City). *IPRD Policy Consulting Report*, Unpublished Manuscript. Guangzhou: Sun Yat-sen University.

Lüthje, B. (2001). *Standort Silicon Valley: Ökonomie und Politik der vernetzten Massenproduktion*. Frankfurt and New York: Campus,.

Lüthje, B. (2021b). Going digital, going green: changing production networks in the automotive industry in China. *International Journal of Automotive Technology and Management*, *21*(1-2), 121-136.

Lüthje, B., & Tian, M. (2015). China's automotive industry: structural impediments to socio-economic rebalancing. *International Journal of Automotive Technology and Management*, *15*(3), 244–267.

Lüthje, B., Hürtgen, S., Pawlicki, P. and Sproll, M. (2013a). *From Silicon Valley to Shenzhen – Global Production and Work in the IT-Industry*. Boulder, Co.: Rowman and Littlefield.

Lüthje, B., Luo, S. and Zhang H. (2013b). *Beyond the Iron Rice Bowl: Regimes of Production and Industrial Relations in China.* Frankfurt/New York: Campus.

Muniz, S.T.G., Belzowski, B.M. and Zhu, J. (2019). "The trajectory of China's new energy vehicles policy", *International Journal of Automotive Technology and Management,* Vol. 19, Nos. 3/4, pp. 257-280.

Pardi, T., Krzywdzinski, M. & Lüthje, B. (2020). Digital manufacturing revolutions as political projects and hypes: evidences from the auto sector. *ILO Working Paper 3*: *The Future of Work in the Automotive Industry*. Geneva/Paris: International Labour Organisation.

Piore, M. J. & Sabel, C. F. (1984). *The Second Industrial Divide. Possibilities for Prosperity.* New York: Basic Books.

Rapier, R. (2019). “Why China is Dominating Lithium-ion battery Production”, *Forbes*, August 4, 2019.

Rosina, M. (2017). “Status of the Rechargeable Lithium-ion Battery Industry Report”, *Yole Développement*, July 2017.

Sanderson, H., Hancock, T., & Lewis, L. (2017, March 5). Electric cars: China’s battle for the battery market. *Financial Times*. https://www.ft.com/content/8c94a2f6-fdcd-11e6-8d8e-a5e3738f9ae4. Accessed 07 July 2021.

Srnicek, N. (2017). *Platform Capitalism*. Cambridge UK: Polity Press.

Taipei Times (2021, January 14). Hon Hai to set up vehicle joint venture. *Taipei Times*. https://www.taipeitimes.com/News/biz/archives/2021/01/14/2003750511. Accessed 07 July 2021.

Thun, E. (2006). *Changing Lanes in China, direct investment, local government, and auto sector development*. New York: Cambridge University Press.

Thun, E., & Sturgeon, T. J. (2017). When Global Technology Meets Local Standards. Reassessing China’s Telecom Policy in the Age of Platform Innovation. *MIT-IPC Development Working Paper 17-001*. Cambridge, MA.: MIT Industrial Performance Center.

Tyfield, D. (2018). *Liberalism 2.0 and the Rise of China: Global Crisis, Innovation and Urban Mobility*. London: Routledge.

Womack, J. P.， Jones, D. & Roos, D. (1990). *The Machine that Changed the World*. New York: Rawson Associates.

Xinhua News. 2021. 20 万吨退役电池，大量流入“黑市”——新能源汽车电池回收乱象调查 (200,000 tons of used batteries into ‘black market’——an investigation on the chaos of recycling NEV vehicles) . http://www.xinhuanet.com/politics/2021-04/12/c_1127321334.htm, retrieved on 10 November 2021.

Yang, T., Luo, S., & Lüthje, B. (2019). Machine Replacing Man? Upgrading and Transformation of Car Suppliers in the Pearl-River Delta 2010-2017. *Friedrich-Ebert-Stiftung Discussion Paper*. FES Office China.

Zhang, L. (2015). *Inside China’s Automobile Factories, The Politics of Labor and Worker Resistance,* New York: Cambridge University Press.

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