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CHOWDHURY Mahbubul Alam

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Development and Progress of Electric Vehicles in China

CHOWDHURY Mahbubul Alam*

Abstract

The rapid development of China's automobile industry has raised concerns about the country's energy crisis, environmental pollution, and bottleneck of sustainable development. Under these conditions, the automobile industry introduced new technologies in automobile manufacturing. Therefore, the development of multienergy, highly efficient, and environmentally friendly new energy vehicles (NEVs) has become the focus of the automobile industry's development. NEVs include hybrid electric vehicles (HEVs); plug-in hybrid electric vehicles (PHEVs); battery electric vehicles (BEVs) or electric vehicles (EVs); and fuel cell vehicles or hydrogen fuel cell vehicles (FCVs). This paper will provide a brief overview of the problems involved in the development of EVs. The main problem with EVs is their large battery size, heavyweight, and high cost. The paper contains suggestions and assumptions made by implementing frugal technology to reduced

* Professor, Department of International Liberal Arts and Graduate School of Humanities and Social Sciences, Fukuoka Women's University

materials, resources used in the production of an EV. The ultimate goal is to reduce costs and bring affordable mass production to markets. It also predicts the future development trend of EVs in China.

1. Introduction

China's miracle economy has been fueled by investment and expanding industry, which has contributed from world factories to global markets. In the late 1970s, hundreds of thousands of rural and urban residents were forced to live with kerosene lamps and no electronics. Kerosene lamps, however, have been replaced by smart lights controlled by voice command or even the mere presence of a person and powered by greener energies. Mail carriers have been replaced by 5G-enabled equipment ensuring that family and friends are only a button press away. Slow trains have been replaced by ultra-fast high-speed rail (The Global Times, July 29, 2021). Additionally, bicycles have largely replaced private cars.

Currently, China is the world's largest EV producer, and the EV industry is dominated by users. In 2020, the country will have produced and sold over 1 million EVs, compared to 366 units sold in the first half of 2008 (Zhang, 2013). This expansion was fueled by substantive incentives to promote EV sales and boost the overall automotive market. EV penetration in 2020 was 9% to 1.2 million units (IEA, 2021, website), and the increase of sales percentages has encouraged producers to make miraculous progress in terms of price, technology, and popularity in the domestic market.

This study, which is based on secondary and archival materials and documents, will provide a comprehensive overview of NEV research and will describe EVs in China. Furthermore, the paper emphasizes

EV market share as well as future markets, prospects, and development. It will investigate the feasibility of implementing cost-effective technological practices. Frugal technology has contributed to a low-cost business strategy of “doing more with less” or “processing more with less” which benefits resources, production, market, and affordability. However, the following is how the paper’s discussion is organized: Section 2, Development of New Energy Vehicles Industry in China; Section 3, Making a Miracle Progress of Electric Vehicles; Section 4, An Assessment and Suggestion for Frugal Technology of Electric Vehicles in China; and Section 5, Concluding Remarks.

2. Development of New Energy Vehicles Industry in China

The rapid growth and development of China’s traditional internal combustion engine (ICE) vehicle industry have raised concerns about petroleum, environmental pollution, and sustainable development. The country has made an effort to find solutions to these problems by developing new energy vehicles (NEVs). NEVs include are hybrid electric vehicles (HEVs); plug-in hybrid electric vehicles (PHEVs); battery electric vehicles (BEVs) or electric vehicles (EVs); and fuel cell vehicles or hydrogen fuel cell vehicles (FCVs). China, the USA, Japan, and several European countries have led to the rapid rise of EVs over the last few decades. This rising trend of EVs is due to several factors, including strong technological progress, cost reductions (especially batteries), government incentives and policy support, driving and parking access advantages, and the availability of public and private charging infrastructure.

1) A Brief Introduction on Electric Vehicles in China

The EV industry has emerged as a critical issue for Chinese policymakers at the national level. The government has enacted policies to encourage the development of EVs. The year 2009 was a defining moment in China's EV development. That year, President Hu Jintao, declared a new energy vehicle development plan " in accordance with the nation's current conditions" (Wei *et al.,* 2013). Until recently, vehicles manufactured in China were widely considered as low-tech and cheap.

Still, replacing Internal Combustion Engines (ICEs), which have dominated the market for many years, with EVs would be difficult. In 2018, EVs accounted for slightly more than 4% of the total 28.1 million vehicles sold in China. That is a higher rate than the USA, which has a rate of less than 2%, and Europe, which has a rate of slightly more than 3%. However, it is insufficient to satisfy the Chinese government. (World Forum, 2019).

Despite recent increased interest, EVs have remained a relatively small market in comparison to ICEs until today (IEA, 2015). Overall, the stock was 17 thousand in 2010, and in a decade, it has increased to more than 10 million worldwide in 2020 (Table 1). In the same year, China's stock of NEVs increased from 1.9 thousand to 4.5 million units. However, the global share of EVs is expected to increase significantly, owing to substantial battery technology improvements and a variety of policies that are hastening the development of the EVs market. EV sales have increased in all three major auto markets: China, the USA, and Europe. Sales increased by 160% in the first half of 2021 from a year earlier, to 2.6 million units, accounting for 2% of new sales in the global automotive market. China remained the world's leading EV market, with 1.1 million vehicles sold in the first

half, accounting for 12% of sales. In the USA, 250,000 units were sold, accounting for 3% of sales (IEA, 2021).

Table 1: Trend of Electric Vehicles (BEV and PHEV) in Some Asian Countries and USA (Units: 1,000)

Country	Type	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	Stock	1.9	6.9	16.9	32.2	85.3	292.7	628.7	1207.7	2288.8	3349.1	4514.1
	Registrations	1.4	5.1	9.9	15.3	73.2	207.4	336.0	579.0	1081.1	1060.3	1160.7
	Market Share(%)	0.01	0.04	0.1	0.1	0.4	1.0	1.4	2.3	4.6	4.9	-
America	Stock	3.8	21.5	74.7	171.4	290.2	404.1	563.7	762.1	1123.4	1450.0	1787.2
	Registrations	1.2	17.7	53.2	96.7	118.8	113.9	159.6	198.3	361.3	326.6	296.3
	Market Share(%)	0.01	0.2	0.4	0.8	0.8	0.7	1.0	1.3	2.3	2.1	-
Japan	Stock	3.5	16.1	40.6	69.5	101.7	126.4	151.3	205.3	155.1	294.0	297.2
	Registrations	2.4	12.6	24.4	28.9	32.3	24.7	24.7	54.1	49.7	38.9	30.1
	Market Share(%)	0.1	0.3	0.5	0.6	0.7	0.6	0.6	1.2	1.1	1.0	-
South Korea	Stock	0.1	0.3	0.9	1.5	2.8	5.9	11.2	25.7	60.6	92.4	146.6
	Registrations	0.1	0.3	0.5	0.6	1.3	3.2	5.3	14.6	34.9	31.8	45.6
	Market Share(%)	-	0.1	0.04	0.1	0.1	0.2	0.3	0.9	2.3	2.1	-
World	Stock	17.0	64.3	183.6	386.3	692.6	1235.7	1988.1	3136.8	5111.9	7167.8	10,288.3
	Registrations	8.2	48.2	118.2	204.1	328.8	546.6	750.6	1172.5	1980.1	2101.7	2,986.6

Note: (–) not available
Source: IEA, 2020, website

2) Government Initiatives

The Chinese government has enacted a large number of industrial policies in order to address problems, such as energy security, environmental pollution, as well as to accelerate the development of the NEV industry. The NEVs industry's process is fraught with difficulties and bottlenecks, and relying solely on a self-sustaining market cannot achieve the ultimate goal of EVs (IEA, 2021). The government has set a target of 70% of new EV sales by 2030. In light of these considerations, the government has issued a number of policies, plans, demonstration projects, fiscal subsidies, and tax breaks. Among these plans are the 13th Five-Year Plan (2016-2020) and the 4th Five-Year Plan (2021-2025), both of which have emphasized the growth of EVs. The main objectives of the 14th Five-

Year Plan have innovation, modernization drive, self-reliance, and self-improvement in science and technology are a top priority. In November 2020, the State Council of China issued the " New Energy Vehicle Industry Development Plan 2021-2035," proposing that by 2025, the sales target of NEVs be about 20% of the total new vehicle sales, and by 2035, EVs will be the mainstream of new vehicle sales. Public sector vehicles will be fully electrified and fuel cell vehicles will be commercialized (IEA, 2021).

Although, China has issued a number of policies to guide and promote the development of China's NEVs industry. The policies for NEVs include reduced taxes, direct subsidies to manufacturers, consumer subsidies, mandated government procurements, and the industrial policy "Made in China 2025" (MIC2025) to promote the NEV industry.

(1) Purchase subsidies

China has provided billions of dollars in direct subsidies to NEV manufacturers. These policies both at the central and regional level subsidized EV manufacturing and sales. For example, BYD, a Shenzhen-based manufacturer that produces electric and hybrid vehicles, received $435 million in subsidies between 2010 and 2015. In 2009, the government began offering EV customers subsidies between 3,000 yuan (US$ 470) and 6,000 yuan (US$ 940). These subsidies were increased in January 2010 to between 5,000 yuan (US$ 785) and 18,000 yuan (US$ 2825). Subsidies range from 40% to 60% of the cost of the vehicle per car for EVs and PHEVs, respectively.

In 2012 " Energy-Saving and New Energy Vehicle Industry Development Plan (2012-2020)," was allocated over $15 billion to support NEVs, EV related infrastructure (Marika, 2017). Purchase

subsidies, on the other hand, were scheduled to expire at the end of 2020, but in the midst of the corona pandemic, they were reduced by 10% and extended until 2022 (IEA, 2021). Subsidies for passenger cars, trucks, and vocational vehicles are 10% lower than the 2019 levels and those for buses and coaches remain unchanged from 2019. The adjustment policy for the first time introduces sales limits. A vehicle price limit for passenger cars of CNY300,000 (US$43,000) including tax (ICCT, 2021). The government announced a green car credit system with a new carbon emission trading scheme (ETS) in 2018, which has a larger vision of carbon neutrality than just individually boosting EV production and sales.

(2) Thousands of Vehicles, Tens of Cities (TVTC) Program

China has laun " The Thousands of Vehicles, Tens of Cities (TVTC) Program." This program, which began in 2009, has been selecting and subsidizing cities to implement EVs. In all of these cities, public sectors, such as buses, taxis, sanitation vehicles, postal vehicles, and official vehicles, were prioritized (Gong, *et al.,* 2013). Green license plates were also introduced for NEVs across the country in 2017, giving owners preferential treatment. Additionally, vehicles with EV plates may be granted special privileges, such as access to restricted traffic zones. Many large cities, including Beijing, restrict drivers of passenger cars from entering the city on specific days based on license plate numbers, while EVs are exempt from such restrictions.

(3) Development of Infrastructure

Infrastructure investment has also increased by local governments, central government, and private-owned charging systems. Private charging stations increased from only 76 stations in 2010 to 6,900 in

2017–a 90% compound annual growth rate. According to the China Electric Vehicle Charging Infrastructure Promotion Alliance, China has the world's most extensive EV charging infrastructure, with 14.1 million charging stations spread across the country, including 764,000 private residence charging poles and 558,000 public charging stations (CAAM, website).

(4) Development of Battery

Over the last two decades, Chinese companies attempting to catch up with Japan and the U.S. in battery technology have focused on battery improvement. The ranking of the lithium-ion battery supply chain in 2020 has quickly surpassed Japan and Korea, which were leaders for the majority of the previous decade. China has achieved successes from raw materials supply to battery manufacturing and vehicle production. China's supply chain is extremely well developed in large part due to the government's aggressive policies to propel the growth and development of this particular industry. According to Bloomberg, China's success results from its large domestic battery demand, 72 GWh, and control of 80% of the world's raw material refining, 77% of the world's cell capacity, and 60% of the world's component manufacturing (Bloomberg, 2020). Additionally, BYD launched its Han EV series in 2020, which features a blade battery and is available in BEV and PHEV variants. It was released with two battery options: 65 kWh for 314 miles and 77 kWh for 342 miles. Its PHEV had a 13-kWh battery, a 2.0-liter gasoline engine, and a 180-kWh electric motor (CAAM, website).

3. Making a Miracle Progress of Electric Vehicles

The growing economy and rising incomes vis-a-vis increase consumer purchasing power and drive up the demand for vehicles ownership. The EVs in China have the potential to produce massive health, environmental, economic, and security benefits. According to Nancy (2020) (MIT Energy Initiative) that analysis, in 2020, EVs make up just 7% of the total of 1.6 million vehicles. By 2025, that share is expected to rise up to 21% of the total 5.4 million. And by 2030, it is up to 37% of the total 11.2 million–close to the government's 40% target. Altogether, 66 million EVs are sold between 2020 and 2030 (Nancy, 2020). In China, the potential benefits of EVs include reduced air pollution, reduced greenhouse gas (GHG) emissions, and reduced reliance on foreign oil. Still, there are many obstacles to overcome before EVs can make more progress. Adoption of frugal cost-cutting technology to do more with less can provide a miracle development future for NEV and EV in China.

1) Increasing Economic Solvencies Population

China has made the most progress in terms of increasing the number of middle-class people. The lower middle class accounts for more than half of the total middle class, while the upper-middle class accounts for only a small percentage of the population **(Table 2)**. There is no doubt, however, that the emergence of a new middle class with spending power comparable to that of developed countries contributes to the expansion of consumer goods demand. The growth of consumer goods sales to the middle class, such as televisions and mobile phones, has already been established, but a new range of products, such as financial services and automobile sectors, are

increasingly being geared toward this group as well. China has owner only 173 units of the car out of every 1,000 people whereas, the USA 837, Australia 747, Italy 695, Japan 591, Malaysia 433, and Russia 373 (McKinsey and Company, 2019). The growing economic solvencies population is catering to the growth in NEVs, and it is expected that this industry will usher in rapid development, while EVs will have a large room for growth as the main NEVs market.

Table 2: Population size of income levels in China (thousand person)

Income (US$ per day)	2009	2015	2020*
BOP ($4-$10)	747,675	431,699	207,489
New MOP ($10-$20)	464,807	630526	578,203
MOP ($20-$100)	90,305	226,063	412,212
TOP (Over $100)	25,232	73,539	185,357

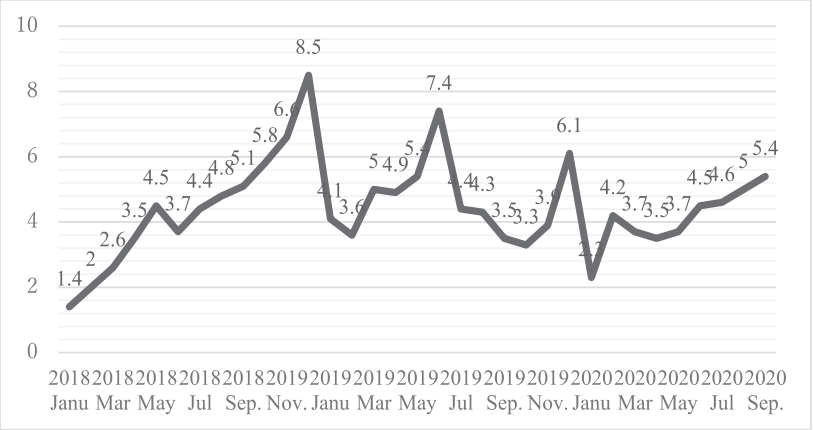
Note: * Estimated
Source:Chowdhury, 2018, 36.

2) Present Trent of Electric Vehicles

Currently, China, Europe, and the United States each have over a million EV and PHVs on the market, with China having the largest market. Due to government initiatives, increased charging infrastructure, and increased manufacturing companies, EVs have seen rapid development in China. China's EV sales have increased steadily since 2013. With an annual growth rate of at least 45% for six consecutive years from 2012 to 2017. It accounted for nearly half of total global sales and more than double the sales in the USA. In the USA, growth in EV sales remained steady at between 20% to 30%, with total sales of around 190,000 and China 500,000 units in 2017 (ICCT, 2019).

However, as a result of the COVID-19 pandemic in 2020, China's EV production and sales have plummeted. According to the CAAM, total EV production in China was 369,000 in the first half of 2020, with total sales of 371,700 It is worth noting that, since the pandemic was gradually brought under control in March 2020, China's EV production and sales have begun to recover gradually. NEV sales are steadily rising, up from 2.3% in January 2020 to 5.4% in September **(Figure 1).**

Figure 1: Sales Share of NEVs in China NEVs in China



Source: CAAM and MIIT, website.

(1) Production of EVs in China

China first experienced a one million vehicles market in 1992 (Chowdhury 2013) and further increased more than 5 million in 2005, which country stood forth raking and became the first raking in the world in production and sale since 2010. The total production of 29 million vehicles produced in 2017 was expected to increase to 40 million by 2025 (CAAM, website). The performance of EV production

in Chinese companies, such as SAIC, FAW, Dongfeng, Changan, BAIC, Chery, BYD Geely, and others in the country producing NEVs **(Table 3)**. In 2018, there were 112 active NEV producers, and by 2020, there will be more than 119. Even assuming extremely healthy sales of 1.5 million NEVs in 2020, that would equate to an average of 12,600 per producer, far short of sustainable economies of scale (Scott, 2020).

Table 3: Trend of Chinese Automobile Industry (Unit)

Items		2012	2013	2014	2015	2016	2017	2018	2019	2020
Production		19,271,808	22,116,825	23,491,900	24,597,600	28,118,794	29,015,434	27,809,196	25,750,650	25,225,242
NEV Production	EV	13,300	14,243	48,605	254,633	388,600	649,617	970,228	1,022,406	1,095,683
	PHV	1,000	3,290	29,894	85,838	98,924	117,201	283,287	220,844	260,001
	Total	14,300	17,533	74,763	340,471	487,526	766,948	1,254,113	1,268,963	1,357,291
NEV Sales	EV	9,640	14,604	45,048	247,482	380,124	634,805	968,443	995,600	1,106,233
	PHV	—	3,038	49,715	83,610	97,295	123,447	270,885	232,474	250,843
	Total	—	17,642	74,763	331,092	477,419	758,367	1,239,933	1,231,970	1,358,585
Exports		1,013,235	943,166	950,000	755,500	708,000	891,000	1,041,000	1,020,000	995,000
Imports		1,132,031	1,195,040	1,430,000	1,101,900	1,041,000	1,215,885	1,108,443	1,085,768	933,000
Market Size		19,306,435	21,984,079	22,833,590	24,944,000	28,028,175	28,878,904	28,080,577	25,796,931	25,311,069

Note: market size = (total local production + imports) – exports), (—) not available.
New Energy vehicles (EVs, PHVs, and FCVs.
Sources: Fourin, (2021), Global Trade Atlas, MIIT, CAAM, website.

(2) Sales of EVs in China

The government has also become a major EV customer. Electric bus sales increased from 1,000 units in 2011 to 116,000 in 2016 (Tim 2018). The most successful EV makers are Chinese auto groups. Four of them-BYD, BAIC, Geely, and SAIC-have achieved large economies of scale and sold more than 200, 000 electric vehicles globally The sales of NEVs are shown in **Table 4.**

BYD sold only 5, 544 EVs in 2015, and 189, 439 EVs up to 2018 largest EV manufacturer in China, due to COVID-19 the has declined to 181,541 EVs in 2019 and further declined to 144,124 EVs in 2020 **(Table 4)**. It is worth noting that China's EV brands developed rapidly in 2020. Among them, BYD has established a solid reputation in the high-end EV market. Since its listing, sales of SAIC-GM-Wuling

Hongguang have continued to rise, occupying a dominant position in the economic vehicle market in China.

Table 4: Sales of Chinese NEV some Manufacturer (Units)

Company	2015	2016	2017	2018	2019	2020
BYD	5,544	32,624	33,020	189,439	181,541	144,124
Geely	7,823	26,102	61,624	70,585	65,611	32,362
BAIC	18,105	46,708	104,050	143,322	85,583	48,672
Changan	863	5,069	29,554	31,524	34,876	29,345
Chery	1,196	7,998	20,021	32,410	62,278	38,926
SAIC	12,370	22,246	59,868	114,346	106,708	229,569
NIO	-	-	-	11,404	20,752	43,304
Great Wall	-	-	3,106	10,779	37,483	55,167

Note: (—) not available
Source: Fourin, 2021,120.

3) Electric Vehicles Related Problems

Since the turn of the century, the Fourth Industrial Revolution, also known as Industry 4.0, has been contributing to the development of cutting-edge technologies such as robots, AI, drones, the internet of things (IoT), and NEVs (Chowdhury, 2020). As the automotive industry is undergoing a period of great changes in electrification, intelligence, and connectivity, intelligent networked vehicles have become an important development direction for the NEVs especially EV automotive industry.

However, the lack of charging infrastructure, the weight, and size of batteries, and the high prices of EVs make them prohibitively expensive for China's middle-class citizens. Batteries are, in fact, expensive. Although EVs require less maintenance and repairs, it can be difficult to find a qualified mechanic to set up or move parts. Furthermore, China's massive manufacturing scale, rising labor costs, and an aging population are all factors that increase the imperative to automate, contributing to the high prices of EVs. However, there

are some significant issues, which are as follows.

(1) Technological Problems

In the midst of the automotive industrial revolution, China's EV industry faces significant technological challenges. Some core technologies are still in their infancy. EV technology entails more than just the design, production, and manufacturing of complete vehicles. However, there is a need for more effort to develop infrastructure and acquire technologies and capabilities to produce EVs that meet future purchasing affordability. Under these conditions, the adoption of new (frugal) technology and innovation that can develop production and processing systems with fewer parts and materials produces low-cost EVs.

(2) Material and Resources

Prices for materials, goods, and commodities used in the manufacture of EVs, such as lithium, nickel, cobalt, manganese and graphite, steel, copper, aluminum, and others, have skyrocketed. According to IEA forecasts, the raw materials used to manufacture EVs will have increased 42 times relative to 2020 levels by 2040. Reserves of the raw materials for batteries are highly concentrated in a few countries. The largest lithium deposits are in South America and East Asia. Around one-third of the world's lithium comes from Argentina, Mexico, Bolivia, and Chile. Nearly 50% of world cobalt reserves are in the Democratic Republic of the Congo (DRC)[(1)], 58% of

(1) The country human-rights activists have raised concerns over conditions there, particularly child labor and harm to workers' health. About 40, 000 children about 16% of the 255,000 people who work in the mines. Workers are often paid less than $2 per day (BBC, Oct.8, 2020).

lithium reserves in Chile, 80% of natural graphite reserves in China, Brazil, and Turkey, while 75% of manganese reserves in Australia, Brazil, South Africa, and Ukraine (UNCTAD, 2020).

Battery production continues to be dominated by China, which accounts for over 70% of the global battery cell production capacity (IEA, 2021). China's share of refining is around 35% for nickel, 50% – 70% for lithium and cobalt, and nearly 90% for rare earth elements(2). Chinese companies invested in Australia, Chile, the Congo, and Indonesia for producing batteries. High levels of concentration, combined with complex supply chains, increase the risks posed by physical disruption, trade restrictions, or other developments in major producing countries (IEA, 2021). As result, these mineral resources have become a new source of geopolitical tensions. Policymakers in the USA and Europe, are increasingly discussing a " race " to secure minerals linked to the energy transition and shore up domestic supplies; the idea of a " new cold war " with China (IEA, 2021).

(3) Batteries Related Problems

EVs rely on batteries. The battery is the most expensive component of an electric vehicle. Rechargeable batteries for EVs include lithium-ion (Li-ion), nickel-metal hydride (NiMH), and lead-acid batteries. The lithium-ion battery is crucial in EVs. Battery costs per kilowatt-hour (kWh) declined from roughly $1,000 per kWh in 2010 to $227 in 2016, but may not fall to the level of ICEs (IEA 2021). The battery must be recharged on a regular basis, which can be done at home, at work,

(2) The rare earth also producing toxic lake in Inner Mongolia made of black sludge and hazardous chemicals that environmental abuses in the supply chain practices (BREITBART, 2021).

while shopping, or at other types of stops while traveling. Because of the high cost, shorter driving distances, longer charging times, and a lack of charging stations, batteries are the main issue. These issues are directly related to the power supply system, which is comprised of batteries.

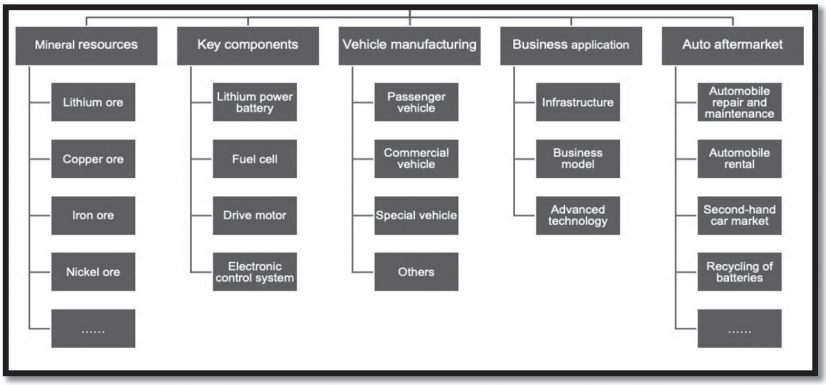
Batteries have varying degrees of durability. The life of a battery varies depending on the technology used, the type of use, storage conditions, extreme temperatures, and the amount of time required to recharge and completely discharge the batteries. Currently, manufacturers estimate the lifetime of a battery and its durability of more than ten years. After ten years of use, a battery that originally held 50 kilowatt-hours, will have lost at most 20% of its capacity (Nature, 2021). Batteries are frequently neither discarded nor recycled. There are many different kinds of batteries, and different kinds of cathode material will end up in the recycling cauldron. This could make it more difficult to separate the various cathode-crystal types.

(4) Industrial Supply Chain Related Problems

As EV adoption grows, these changes will naturally reduce suppliers' potential addressable market. To produce a complete vehicle, the vehicle assembly plant requires raw materials and components, labor, supplies, and utilities **(Figure 2)**. The share of EVs' value added by component suppliers might total 35% to 40%, compared with 50% to 55% of an ICE-powered car (PWC, website). As EVs take an increasing share of sales, the supply chain will become increasingly important. With the increasing demand for EVs, as well as the convergence between engineering and modern technology, and battery supply chain must also adapt its offerings. EV batteries, like

many high-technology goods, have a complex supply chain in which production is separated into stages, and those stages can be completed in different locations.

Figure 2: The Structure of Chinese EV Supply Chain



Source: Daxue Consulting (2021)

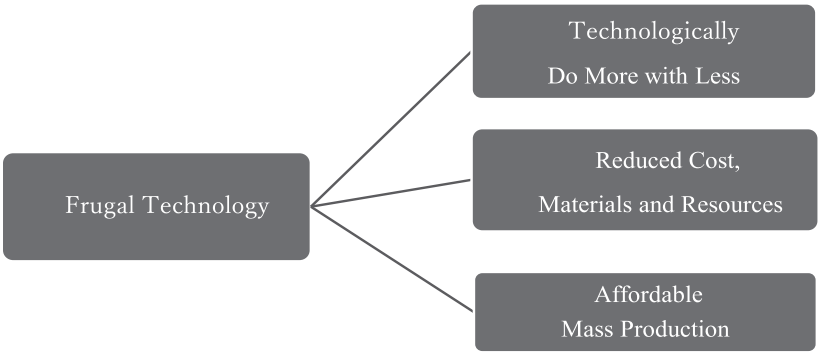
The battery is the most important component of an EV, which differs from the traditional automobile industry chain. As a result, mineral resources, such as cobalt, nickel, manganese, graphite, and lithium, which are important raw materials for batteries, are found upstream in the EV industry chain **(Figure 2)**. Materials availability issues can disrupt supply chains. Furthermore, battery prices have steadily declined in recent years, and that share is likely to fall significantly over time. Nonetheless, these batteries are primarily manufactured by companies outside of the traditional auto supply chain, posing new challenges to legacy suppliers. The fact that some EV battery suppliers are developing expertise in the production of electric powertrains emphasizes the risk (PWC, website).

4. An Assessment and Suggestion for Frugal Technology of Electric Vehicles in China

The EV is an innovative concept in the world automobile industry. This innovation refers to the development of new products, methods, types of raw materials, and markets. Frugal technology is an innovative efficient technology, which reduces materials, costs and pushes up affordable mass production. The concept of " frugal technology " shown in **Figure 3**, these are " technologically do more with less; " " reduced material, resource and cost; " and " affordable mass production " contributes to business models of an EV company.

The frugal technology makes it possible to " do more with less," which contributes to reduced production materials and resources. Frugal technology emphasizes the use of lightweight materials, such as high-strength steel, aluminum, or glass fiber-reinforced polymer composites, to replace heavy steel components.

Figure 3: Approach of Frugal Technology



Source: Compiled by author

According to the METI (Ministry of Economy, Trade, and Industry, Japan) the weight concerns, an EV is 2.1 tons which battery weight is 550 kg contributing 26% of total weight. An EV weighs from 300 kg to 600 kg heavier than a gasoline vehicle. This means an EV runs it consume more energy or power due to heavyweights (METI, website). One method for reducing weight is to make body components out of lighter materials, such as carbon-fiber-reinforced plastic (CFRP) or polymer. Another way to reduce vehicle weight is to reduce the weight of the vehicle's wiring harness. As a result, EV manufacturers are increasingly relying on " light-weighting," or the use of lighter but stronger materials. Renault first proposed the concept of frugal engineering, claiming that frugal innovations could be a great opportunity for a successful business (Chowdhury, 2019).

Given some of the frugal approaches being considered, the EV body would cost nearly the same as or slightly more than an equivalent conventional body of the same material. **Table 5** shows lightweight material aluminum or polymer composites, were used for the body a similar cost premium would be incurred for both ICE and EV bodies.

Table 5: Frugal Approach of Material Use in EVs

Materials	Reduced Weight
Magnesium	30-70%
Carbon fiber composites	50-70%
Aluminum and Al matrix composites	30-60%
Titanium	40-55%
Glass fiber composites	25-35%
Advanced high strength steel	15-25%
High strength steel	10-28%

Source: Energy Efficiency & Renewable Energy, website

Research and development into lightweight materials is essential for lowering their costs, increasing their ability to be recycled, enabling their integration into vehicles, and maximizing their energy economy benefits. A 10% reduction in vehicle weight can result in a 6% to 8% increase in fuel economy. Replacing cast iron and traditional steel components with lightweight materials, such as high-strength steel, magnesium (Mg) alloys, aluminum (Al) alloys, carbon fiber, and polymer composites, can directly reduce the weight of a vehicle's body and chassis by up to 50% and therefore reduce a vehicle's fuel consumption.

Renault-Nissan has used frugal engineering to become a major global manufacturer of both low-cost vehicles and EVs. The BMW i3 is made of carbon, a costly material that is five times lighter than steel. The BMW i8 drive train and chassis are aluminum, which reduces the weight by 30% compared with steel and the passenger cabin is almost entirely carbon fiber. As a result, the BMW i8 weighs 1,490 kg, which is in line with conventional sports cars, despite its heavy battery (Radjou and Prabhu, 2012, Chowdhury, 2019).

2) Reduced Materials, Resources, and Cost

The body of an EV must perform all of the functions of an ICE body, but it must also provide sufficient space for the batteries. There is also strong motivation to make the body lighter in order to offset the weight of the battery. Because it takes less energy to accelerate a lighter object than a heavier one, lightweight materials have enormous potential for improving vehicle efficiency.

The costs of Li-ion batteries are expected to fall due to advancements in battery design and cost-effective manufacturing techniques. A number of laboratories have been experimenting with

low-cobalt or cobalt-free cathodes in order to replace high-cost materials, such as cobalt. Materials scientist Arumugam Manthiram of the University of Texas at Austin, and Sun Yang-Kook of Hanyang University in Seoul, South Korea, who has achieved comparable performance in cobalt-free cathodes (Nature, 2021). As a result, it eliminates the high-priced metal from its batteries.

The frugal approach to reducing material and resource burden is to improve battery recycling, so that the valuable metals in spent batteries can be efficiently reused. China is the country with the fastest growing recycling capabilities. For example, Foshan-based Guangdong Brunp–a subsidiary of Contemporary Amperex Technology Co., Limited (CATL), China's largest maker of lithium-ion cells–can recycle 120,000 tons of batteries per year. That is enough to power more than 200,000 EVs, and the company can recover the majority of lithium, cobalt, and nickel (Melin, 2021). Battery and automakers are already spending billions of dollars to reduce the costs of manufacturing and recycling EV batteries, spurred in part by government incentives and the anticipation of upcoming regulations (ICCT, 2020).

According to some natural scientists and economists, one potential step toward the adoption of EVs powered by electricity generated by renewable sources of energy, such as sunlight, wind, and water (IRENE 2019). Wind and solar contribute significantly to the EV being cleaner than they would be in other places where energy is the primary source.

Wireless charging technology is another frugal approach that makes EV charging easier and more convenient. Wireless charging was an option, significantly improving the chances of EV adoption. Overall, charging issues are the most significant barriers to EV

adoption, and wireless charging can significantly help to reduce those barriers. The availability of wireless charging increases purchase intent, will bring new owners to EVs and will help expand the market.

3) Affordable Mass Production

EVs will be accepted by mass production and the general public. It takes time to achieve comparable purchase prices for ICE vehicles. China's government is heavily investing in the development of EVs. Businesses and governments around the world are looking for technological innovations that will reduce costs and increase the use of EVs. In fact, government policy has a significant impact on EV sales and market trajectory. Frugal technology contributes to the continuous reduction of battery costs, as well as increasing battery performance, increasing production volumes, and offering market-affordable prices. Frugal technology, whether it is through R&D to develop new products or process technologies, improves mass-market affordability.

5. Conclusion

The EVs market has shown excellent performance in China since 2010. Chinese automakers to step up research and development of strong EVs, high-efficiency advanced technologies so as to prompt the long-term development in these sectors. The frugal production system evolved from resource-based technology to eliminate some unnecessary parts, saving significantly more resources and lowering production costs in order to comply with stringent squeeze final production to contribute at low costs.

EVs, however, continue to have a small market share of new

passenger vehicles when compared to ICE vehicles. ICE vehicles will likely continue to dominate the market for some time, but EVs may eventually replace ICE vehicles. However, EVs are still less mature and reliable in terms of lifespan, range, charging station availability, and efficient technicians or engineers. More incentive policies, plans, and government support, as well as subsidies, are required for further development in this sector. In this context, China must strengthen its domestic technology and research capacities, with a focus on low-cost technology to be used in charging infrastructure, battery swapping, vehicle body, motor, and other areas that will accommodate the rapid growth of EVs in the near future. Last but not least, as more people can afford to buy EVs, frugal technology, including battery technology, and consumer behavior, are important factors in China's affordable mass production.

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