Current Situation in The Development of Electric Vehicles

Xin Hong*

School of Mechanical and Automotive Engineering, Qilu University of Technology, Jinan 250353, China

* Corresponding Author Email: 201801070011@stu.qlu.edu.cn

Abstract. The electric vehicle officially entered the history books in 1881 when the first electric car was invented and built by French inventor Gustave Trouvé. At the beginning of the twentieth century, the passion for electric vehicles had reached its peak. As the global economy boomed, electric vehicles became popular, selling far more than other powered vehicles. Later, due to the discovery of huge oil fields, lower petrol prices, improved gasoline vehicle's technology, and better road infrastructure, people were gradually abandoning electric vehicles. By the end of the twentieth century, due to the harsh environment and energy shortage, people are focusing on electric vehicles again, becoming the focus of the times. This paper will introduce environmental pollution, the energy crisis, and the need to develop electric vehicles. It will analyse the history and current status of the development of electric vehicles in several countries and regions. Technical aspects of electric vehicles such as range, battery recycling, and safety issues will also be discussed.

Keywords: Electric vehicle; fuel vehicle; battery; safety; countries.

1. Introduction

Sustainable development has been widely mentioned as a principle for decades and is described as development that meets the needs at present without compromising the future generations' needs. Considering the environmental damage caused by the emissions of conventional fuel vehicles and the energy consumption of petrol, more attention has been turned to electric vehicles as a potential solution for the sustainable development of human road transport [1]. In this situation, electric vehicles have continued to evolve, revolutionizing technology and breaking many of the records held by gasoline vehicles in decades. Therefore, it is important to explore the current state of development of electric vehicles and identify some of the factors that are limiting their further development.

Bolin told a hearing in the U.S. House of Representatives that if we obtained all fossil fuels now and ran out of them in the short term, carbon dioxide levels in the atmosphere would be many times higher than pre-industrial levels, which will surely lead to a catastrophic global climate. Suppose humans continue to be indifferent and maintain this trend in the use of fossil fuels. In that case, the resulting greenhouse warming effect of increased carbon dioxide will be the same as the most pessimistic models currently suggest: 50 years from now, warmth at high latitudes will reach a critical level, and the retreat of ice in Antarctica will continue at a rate visible to the naked eye. And once the melting starts, it could be irreversible, and it will be done in a short time, causing sea levels to rise by about five meters on most coasts. This will lead to many countries being submerged by the sea, which will cause more damages to human beings [2]. It is clear that current fuel-powered vehicles are contributing significantly to greenhouse gas emissions [1]. In addition, gasoline vehicles emit greenhouse gases and emit kind of harmful gases, causing incalculable harm to the environment. In 2013, global economic losses from air pollution were equivalent to the combined GDP of India, Canada, and Mexico, while China lost about 10% of its GDP that year due to air pollution. At the same time, according to data provided by the World Bank, diseases caused by air pollution from cars are increasing, outstripping the economic influenced by diseases such as AIDS and tuberculosis [3]. So people naturally think of the forgotten electric Vehicles because the emissions of electric Vehicles are extremely low. A study by Vliet in 2011 showed that in the Netherlands, there would be little investment if electric vehicles were integrated into the Dutch grid, apart from the costs incurred in coordinating the supply of electricity to charge the electric vehicles [4]. This does not require excessive additional costs than diesel and petrol vehicles, but electric vehicles can reduce carbon

dioxide emissions by more than 70%. Even in countries and regions where the burning of fossil fuels is the main way of generating electricity, the overall reduction in carbon emissions is 54%, which is an impressive figure.

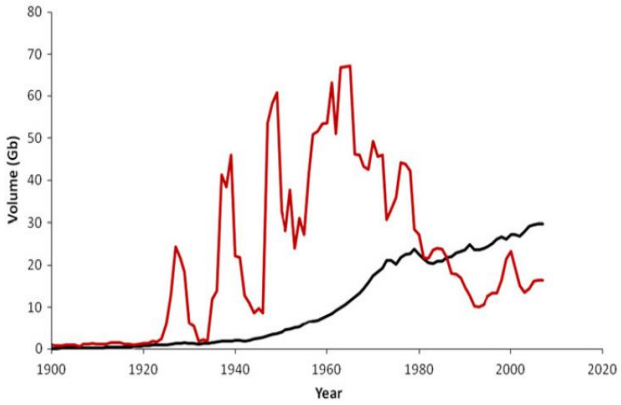


Fig.1 Global trends in production and discovery of conventional oil

As shown in Fig.2, Kerr, R.A, in 1998, believed that the existing oil resources on the earth would be exhausted within two centuries and that new exploration adds far fewer oil resources than is consumed every day [5]. At the same time, plenty of others predict that there will be a visible peak in conventional fossil fuel extraction and then a steep drop. Sorrell S makes a similar point, arguing that global oil will fall into crisis by 2030 [6]. Governments of various countries have noted this problem and come up with appropriate measures to deal with it. And electric cars can obviously use less oil and make the environment better. So many countries have begun to strongly encourage and support the development of electric vehicles. China has introduced many electric vehicle policies to encourage the development of new energy vehicles based on battery technology. By 2040, Europe plans to phase out the use of internal combustion engines (gasoline and diesel) and switch to new energy vehicles powered by other energy sources. These measures will undoubtedly play a big role in promoting the development of electric vehicles [2]. At the same time, global car companies have begun to develop cutting-edge technologies such as autonomous driving, and electrified cars can be better combined with them. Making our transportation system more secure, efficient, and safe. Therefore, in the long run, the rise of electric vehicles is inevitable.

2. Current status of electric vehicles in different countries

2.1. China

As seen in Fig.2, due to the rising living standards of the Chinese people and the large population base, China became the world's largest car market in 2019. China is a major oil importer, more than 50% in 2015. China's external dependence on oil exceeded 60% for the first time and is expected to rise to 80% by 2030, which makes the country's energy problem increasingly serious. In addition to the energy problem, the carbon emission caused by the automobile industry is becoming more and more serious. The serious energy and environmental problems have forced the Chinese automobile industry to reform and transform. Therefore, the Chinese government attaches great importance to the development of electric vehicles and continues to pay attention to and support the research and development of electric vehicles. To promote the development of electric cars, the Chinese government launched a two-wheeled electric cars demonstration project. The expansion from the initial public sector and then to the private sector has led to more and more car companies undertaking research and development into electric vehicles. It has brought the public up close to electric vehicles. At the same time, the Chinese government has enacted a series of incentives that allow the entire electric vehicle industry to grow visibly. Chinese car companies like BYD, Chang'an, and Chery have all made significant efforts to develop and promote their own electric vehicles. Electric car sales have

increased sharply since 2013[7]. By 2015, the number of electric vehicles in China surpassed that of the United States for the first time, and the number has been maintaining steady and continuous growth. However, due to the late start of the Chinese automotive industry, knowledge, and technology are very backward. There are five core technologies known to the electric vehicle industry driving system arrangement and control, energy management and control, battery management, transmission system control, motor design, and control. However, China does not have the patent of these technologies, which is a big gap with other countries and does not have any competitive advantage in innovation [8]. However, Chinese automobile enterprises take advantage of low manufacturing costs and a large local automobile market to solve the problem of backward knowledge and technology, which will threaten established carmakers in other countries that cannot be ignored. Particularly in the manufacture of lithium batteries, China has become dominant in this area due to its strong manufacturing capacity and low prices. In 2020, with China fast-tracking the COVID-19 issue, the country had created incentives for electric vehicles to boost economic recovery, which is heating up the industry again.

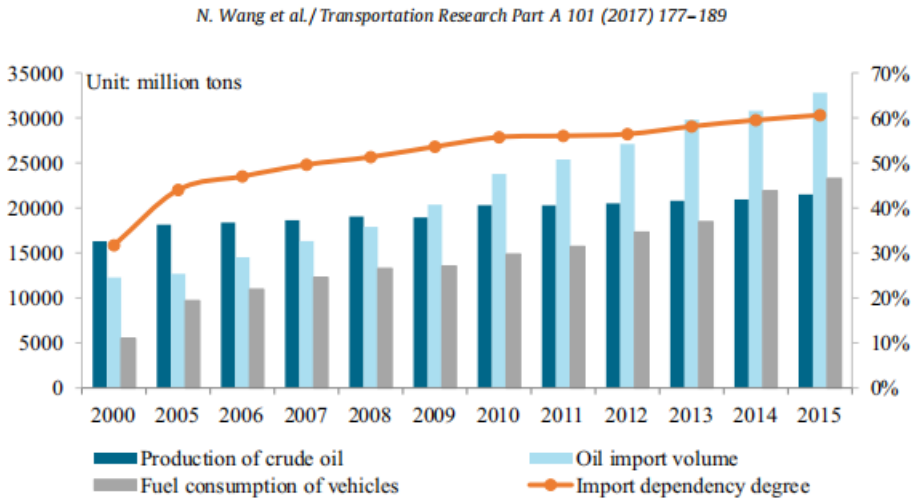


Fig.2 China's oil import dependency degree and fuel consumption of vehicle for 2000-2015

2.2. The U.S.

The electric vehicle industry in the United States started very early. In the last century, the United States Congress passed the Electric and Hybrid Vehicle Research, Development, and Demonstration Act, promoting the development of electric vehicles by means of legislation and financial subsidies. In April 2009, to rescue the U.S. auto industry from the financial crisis, the U.S. federal government vigorously supported the development of new energy vehicles. The United States accounted for 22% of global patents in key technologies for electric vehicles by 2012. To further promote the development of the electric vehicle market, the U.S. government has launched a number of initiatives to accelerate the development of electric vehicle technology. At the same time, efforts are being made to install charging infrastructure to promote consumer acceptance of electric vehicles. Over the past 30 years, the United States has invested $200 billion in parallel hybrid electric vehicles, hybrid electric vehicles [9]. All these initiatives make the US become the world's largest EV market until 2015. The US market is highly competitive, especially in the IT and electronics industries, among the world leaders. However, the U.S. electric vehicle supply chain faces some problems. Although the United States participates in battery development with suppliers, it does not produce its own batteries. The US economy has been badly affected by COVID-19, so the U.S. government has proposed a "green New Deal" stimulus package, which includes a net-zero emissions target, as well as investment and job creation in sustainable energy infrastructure and industries, which will contribute significantly to the development of electric vehicles [10]. On 5 August 2021, U.S. President Joe Biden signed an executive order setting a target for half of all new vehicles sold with zero emissions by 2030 and

proposing new vehicle emissions rules to reduce pollution until 2026. Even though Biden's goal is not legally binding, the US will lean more resources towards the electric vehicle industry in the future. Biden also called for $174 billion in government spending to promote electric vehicles, including $100 billion in consumer incentives. The Senate's bipartisan infrastructure bill includes $7.5 billion to build electric vehicle charging accounts.

2.3. The European

Europe is a global leader in conventional fuel vehicles, which will significantly boost the development of electric vehicles. Since 1990, the establishment of the European "Electric Vehicles in Cities" association has greatly accelerated the feasibility study of electric vehicles. It has made rapid technological progress in the field of electric vehicles. Europe's first electric cars were mass-produced in 1995. Since the beginning of the 21st century, the electric vehicle industry has developed rapidly in Europe, and the number of electric vehicles has continued to increase. European countries have formulated a lot of policy incentives and economic support for the electric vehicle field. For example, France invested 1.5 billion francs in a lump sum. It allocated another 500 million francs to purchase electric vehicles for government use and the construction of charging stations and other infrastructure for electric vehicles. In April 2014, the EU adopted a directive on deploying alternative fuels, requiring EU member states to develop national policy frameworks to facilitate the market development of electric vehicles and their infrastructure. In addition, some member states, such as France, the United Kingdom, Germany, Spain, and many others, have strongly supported the development of electric vehicles in their countries. In 2014 alone, 97,791 electric cars were sold in Europe, increasing 50.3% from the previous year. At the same time, the European Automobile Commission's open, cooperative research enables the technical knowledge of various automobile enterprises to be widely exchanged and disseminated, which has allowed European cars to grow rapidly and become world leaders in areas such as advanced driver assistance systems (ADAS). But in semiconductors, the European supply chain missed the best opportunity to compete, resulting in a lack of exposure to infotainment systems and expertise in energy storage batteries and systems [11]. 2020 January, with tougher carbon emission standards for motor vehicles in Europe, a major push towards electric vehicles is imperative. Meanwhile, after COVID-19, Europe has adopted a series of electric vehicle policies that will allocate hundreds of billions of euros to investment in renewable energy, clean hydrogen, and sustainable transport, which will trigger an explosion of European vehicles [10].

2.4. Japanese

In 1965, the Japanese government started developing electric vehicles, and it was one of the first countries to develop electric vehicles. In 1979, the Japanese government enacted the Environmental Protection Law, which elevated energy conservation and environmental protection legal. At the same time, Japanese schools have developed a curriculum that fosters habits of energy conservation and environmental protection in schools, which has a good impact on consumer demand. In 1997, production of the hybrid Prius began, the first mass-produced hybrid car in the world. Japan has invested heavily in hybrid electric vehicles and has developed and marketed them more than any other country except the United States [12]. It is a world leader when it comes to low fuel consumption, low emissions, and improved driving performance of hybrid power systems. Affected by the financial crisis in 2008, Japan's traditional fuel car industry has been in a slump, but the sales of electric cars have continued to rise. The Japanese government has also implemented a "green tax" policy for new energy vehicles to encourage and develop the electric vehicle industry. In 2013, in Japan's current new car market, the several top sales were hybrid cars. Toyota has done particularly well because it continues to lead in electrification. In Japan, where competition is fierce, Toyota has maintained a highly dominant position in the electrification of its vehicles as it continues to upgrade its technology to stand firm [13]. As of 2014, Japan has registered 100,000 electric vehicles, ranking third in the market. Japan is one of the world's leading electric vehicles markets, largely due to technology

leadership in batteries and the huge success accumulated by Nissan's original technology [11]. According to relevant statistics, in 2019, Japanese passenger car sales accounted for 65% of pure fuel cars, about 34% of hybrid cars, and only about 0.5% of pure electric cars. The mainstay of Japanese cars is still pure fuel and hybrid vehicles. However, now the global automotive trend is moving towards pure electric vehicles, and Japan is relatively less advanced in this segment.

3. Electric vehicle technology

3.1. Battery life and charging stations

Table.1 Basic technical performance of battery types used in EVs [14]

Battery type	Lead-acid	Ni-Cd	Ni-MH	Lithium-ion
Energy density[a](W/kg)	30-50	48-80	60-120	110-160
Power density[b]	180	150	250-1000	110-160
Nominal voltage	2V	1.25V	1.25V	3.6V
Overcharge tolerance	High	Moderate	Low	Very low
Self-discharge	Low	Moderate	High	Very low
Operating temperature	-20-60℃	-40-60℃	-20-60℃	-20-60℃
Cycle life[c]	200-300	1500	300-500	500-1000

a: Chargeable electric energy per weight of battery pack
b: Proportion of dischargeable electric energy to charged energy
c: The number of charging/discharging cycles in battery's entire life

With the promotion of electric vehicles, more and more people are paying attention to electric vehicles. However, the short range of electric vehicles, the long charging time, and the lack of charging piles currently affect the further development of electric vehicles. Battery capacity is the main parameter that affects the endurance of electric vehicles [15]. According to Table.1, we can know that, Lithium-ion batteries compare favourably with other batteries in terms of high energy efficiency and power density. This allows them to be designed to be lighter and smaller in weight and size. In addition, other advantages of lithium-ion batteries include broad operating temperature range, fast charging capability, no memory effect, relatively long cycle life and a low self-discharge rate, so lithium battery is mainly used in the industry, and the energy density of lithium battery is increasing in recent years. In 2015, the average energy density of lithium batteries was only about 100Wh kg-1. However, the energy density of lithium batteries has exceeded 300Wh kg-1 in 2019 and is expected to reach 500Wh kg-1 by 2030. This will greatly increase the capacity of the battery and thus greatly increase the range of electric vehicles. Table.2 shows several Li-ion batteries with different cathode materials used by some famous EV battery pack manufacturers. LCO is the first cathode material that has been used for Li-ion batteries. It has good electrical properties and is easy to prepare. But the scarcity of cobalt led to a high price, so researchers at the time started to look for alternatives. the main advantage of LMO for lithium-ion batteries is that manganese is abundant in the earth and the cost is very low. At the same time, his rate capability and cycling ability are extremely good. However, the capacity of LMO lithium-ion batteries is very low. The solubility of manganese metal in the electrolyte is very high at high temperature. It has a large loss in both reserve and cycling. Whereas LFP lithium-ion battery is extremely stable and also not easy to decompose at high temperature. It also has the advantages of non-toxic, cheap and can be recycled thousands of times, so it is favored by electric vehicle battery manufacturers. The NMC lithium-ion battery has excellent specific energy and specific power, but it is not stable at high temperature. It can be seen that at this stage, these lithium-ion batteries are still some shortcomings, so in the future stage want to battery breakthrough, must find better materials. Because for now, and fuel cars, compared to the range of electric vehicles is still a major factor limiting the development of electric vehicles [14].

Table.2 Selected types of lithium-ion batteries with battery packs manufacturers and EVs developers with their 21st Century EVs

Specifications	LCO	LMO	LFP	NMC
Nominal voltage	3.90V	3.70V	3.40V	3.60-3.70V
Charge limit	4.20V	4.20V	3.60V	4.20V
Cycle life	500	500-1000	1000-2000	1000-2000
Operating temperature	Average	Average	Good	Good
Specific energy (Wh/kg)	155	100-120	160	200
Specific power	1C	10C, 40C	35C	10C
Thermal runaway(℃)	150	250	270	210
Safety	Poor	Average	Very good	Good
Cost	High	Low	Moderate	Moderate

LCO: Lithium Cobalt Oxide
LMO: Lithium Manganese Oxide
LFP: Lithium Iron Phosphate
NMC: Lithium Mixed Nickel-Manganese-Cobalt Oxide

In addition to the relative lack of endurance of electric vehicles, the charging problem of electric vehicles is also a noteworthy factor. At present, there are currently two modes of battery energy replenishment for electric vehicles, a direct charge mode for the battery and a replacement mode for the battery. It now takes around 12 hours to fully charge an electric vehicle, and even set up a fast-charging station can take several hours to fully charge it. The establishment of charging stations is one of the necessary conditions for the development of electric vehicles. Today, most cities are land-strapped, and the land costs are high [16]. Although, in the long run, the investment in the construction of electric vehicle charging stations can pave the way for the large-scale rise of electric vehicles, it takes a long time to recoup the cost of the initial investment. At the same time, charging technology for electric vehicles is always being improved, requiring charging product upgrades over time, while old-fashioned charging equipment will be rapidly phased out. And now, each car brand does not share the charging facilities, which further increases the upfront investment. In addition, the charging time of electric vehicles is long, and the area of urban charging stations is limited, which is not suitable for vehicles to stay for a long time. This is also a huge challenge for the construction of charging infrastructure [17]. The power change mode has many advantages over the charging mode. Orderly charging can effectively reduce the charging cost and the peak electricity burden. The whole process takes only three minutes, which is extremely convenient. In addition, the electrical changing station required by the electrical changing mode covers a small area, which can greatly reduce land use. However, we need to prepare a lot of batteries to make the changing mode work normally, which increases the investment of capital and greatly increases the number of batteries to be phased out.

3.2. Battery elimination

Batteries have a life span. Although technology continues to improve and the life cycle of lithium-ion batteries continues to grow, they will always be eliminated after a long time of use. By 2030, more than 5 million metric tons of lithium-ion batteries will have been scrapped. Lithium batteries contain many harmful heavy metals, such as Cr, Co, Cu, Mn, Ni, Pb, and Ti. If discarded directly, it is easy to pollute the soil and groundwater and cause a great negative impact on the ecological environment [18]. At the same time, as more and more electric vehicles use lithium batteries, the consumption of lithium will grow in the future, and the phase-out of lithium batteries will grow significantly. Therefore, the disposal of used batteries is a public health and safety issue. Although there are some methods to recycle batteries at the present stage, as given in Fig.3, the cost is high, and the recovery value is small, leading to the battery recycling industry's lack of development [19]. At the same time, if the used battery is directly eliminated because it contains a lot of heavy metals,

it needs to spend much money to dispose of. So, recycling these batteries to reduce environmental pollution and promote the sustainable development of the electric vehicles market has become a pressing challenge today.

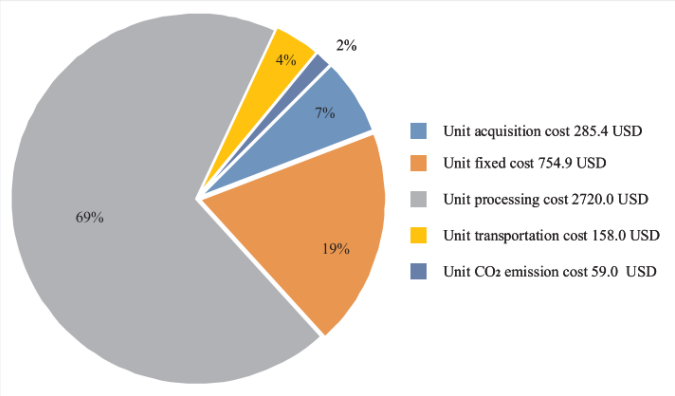


Fig.3 cost break: per unit of battery recycling

3.3. Security

With the growth of electric vehicle sales, the incidents of electric vehicle batteries fire have attracted more and more attention. Look at Fig.4, a global automotive premier brand, Porsche's Tycan, suffered spontaneous combustion in February 2020, raising serious questions about the safety of electric vehicles. At the same time, as the battery's energy density increases, it becomes more dangerous if the energy is accidentally released [20]. In general, there are three common scenarios for electric vehicle fires. The first is a charging fire. As electric vehicles have just entered the public, many people cannot use the correct charging method. At the same time, due to the accelerated roll-out of charging posts, enterprises lack the management and maintenance of them. In addition, overcharging can also pose a certain threat to the battery. The second type of fire is caused by aging battery parts or by flooding the battery box. The battery circuit may be unconnected because of aging or water immersion, resulting in a local short circuit. The third cause of the fire is the violent impact brought to the battery by the collision of electric vehicles, which can easily damage the battery pack structure and short circuit. At present, the battery case structure, which can cope with collision well, has not been effectively popularized. Therefore, it is necessary to pay more attention to battery safety research. The essence of battery fire caused by vehicle collision is battery short circuit, but this is very different from the electrical short circuit under normal circumstances. The existing research results on battery safety cannot be directly applied [21].



Fig.4 Porsche Tycan spontaneous combustion

4. Conclusion

Considering the energy and environmental impacts of conventional vehicles, electric vehicles could be a good solution to meet the sustainable development of road transport. This article describes the current global situation of environmental hardship and energy shortage and the current status of electric vehicle development in several countries and regions. We can see that the development of electric vehicles is a necessity of the times, and every country is trying to make a breakthrough in this direction. At the same time, the development of electric vehicles is still in its infancy. It has a long way to go compared to traditional fuel vehicles, which requires us to invest more and increase research and development to solve some related problems. There are decisive factors in the development of electric vehicles, especially in terms of range and battery energy replenishment. Although the energy density of batteries is increasing and the range is growing as a consequence, the issue of range is still one of the main focuses for electric vehicles in the future. There are two ways of replenishing the battery's energy, and each of them has its own advantages and disadvantages for the development of electric vehicles. Direct charging requires us to build charging stations, and although fast charging technology is now available, this also requires sufficient time to replenish the charge. The other method is the swap mode, and although it only takes three minutes to swap batteries, a large number of batteries need to be prepared in advance to execute this mode. At the same time, every electric car has lots of batteries, which is a consumable product and will be obsoleted after a certain number of years of operation. There are many heavy metals in batteries that are harmful to the environment and human body, and how to deal with them has become a challenge. Recycling technology is not mature enough at the moment, and we need to find better ways to deal with them. And with the development of electric vehicles, the issue of electric vehicle safety is gaining more and more attention. Despite its shortcomings, the electric car is very relevant to the needs of the times and meets the requirements of sustainable development. In the future, the development of electric cars will surpass that of traditional fuel cars, and it is worthwhile to look forward to it.

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