Exploring the Future of Electric Vehicles in China: Market Trends, Government Policies, Carbon Emissions and Technology Development

Yuling Liang [1, a], Yuanzhe Li [2, b, *]

[1] EUNCET Business School, Universitat Politecnica de Catalunya, Barcelona, 08034, Spain

[2] Transportation Design Institution, China Academy of Art, Hangzhou, 310002, China

[a] lyl06222021@163.com, [b, *] yuanzhe1227@gmail.com

* Corresponding Author Email: yuanzhe1227@gmail.com

Abstract. China is a leader in the production and adoption of electric vehicles (EVs), with a rapidly growing market and supportive government policies. With a goal to reduce air pollution and dependence on oil, China has set a target of having 5 million EVs on the road by 2020 and is taking various steps to encourage the development and use of electric vehicles. The Chinese government has established a number of policies to support the development of EVs, including tax incentives, subsidies, and the development of charging infrastructure. In this paper, market trends, government policies, carbon emissions and technology development have been systematic analysed, China's strong commitment to the development of EVs is expected to play a key role in shaping the future of the automotive industry. Design students can play a role in reducing carbon emission by designing lightweight, aerodynamic, and sustainable materials cars. EVs have the potential to significantly reduce carbon emissions from the transportation sector and will continue to gain market share in the coming years, but it is unlikely that ICEVs will be completely replaced in the near future.

Keywords: Electric Vehicles; Market Trends; Government Policies; Carbon Emissions and Technology Development.

1. Introduction

The transition from traditional internal combustion engine vehicles (ICEVs) to electric vehicles (EVs) has been gaining momentum in recent years. The growing demand for EVs is driven by the need to reduce carbon emissions, improve air quality, and support the transition to a low-carbon economy [1]. According to a report by the International Energy Agency (IEA), the global electric car fleet is expected to grow from 5 million vehicles in 2017 to 280 million vehicles in 2040, and the share of electric cars in the global car fleet is projected to reach 40% by 2040 [2]. A report by the National Renewable Energy Laboratory (NREL) in the United States found that widespread adoption of electric vehicles could reduce greenhouse gas emissions from the transportation sector by 80% by 2050 [2-4].

It is important to note that the exact extent of this reduction will depend on the source of electricity used to power the EVs. The emissions from EVs can be reduced even further as renewable energy sources become more prevalent in the power mix. Furthermore, a study by the Union of Concerned Scientists estimated that, on average, electric cars produce less than half the global warming emissions of a typical new gasoline car over their lifetimes [5]. The study by the International Council on Clean Transportation (ICCT) found that the average EV on the road today generates about half the emissions of the average ICE vehicle in Europe, and about one-third the emissions in California. China has made efforts to adopt new energy vehicles, including electric vehicles, to address air pollution and reduce dependence on foreign oil [6]. The government has implemented policies such as subsidies and mandates for EV purchases by government agencies and state-owned enterprises, contributing to the rapid growth of the EV market. However, the market's future growth may depend on government support and technology advancements. The shift towards EV adoption has been observed in cities like Shenzhen, where the bus fleet has become fully electrified. The benefits of EV

adoption include increased efficiency, lower maintenance costs, higher conversion of electrical energy to power, and lower carbon emissions. According to a 2020 Consumer Reports study, EV owners spend 60% less on fuel compared to internal combustion engine vehicles. As of September 2020, new energy vehicles make up 12.6% of total motor vehicle ownership in China [7-8].

2. Difficulty in Developing Electric Vehicles in China

The development and widespread adoption of electric vehicles (EVs) in China faces several challenges in 2023. A primary hindrance is the inadequate charging infrastructure, which cannot accommodate the increasing number of EV drivers [9]. In response, China's government has been investing in constructing more charging stations and incentivizing private companies to do the same. This could be achieved through funding, tax breaks, or other financial incentives, and by establishing regulations and standards to ensure the reliability, safety, and efficiency of the charging infrastructure (**Figure 1**).

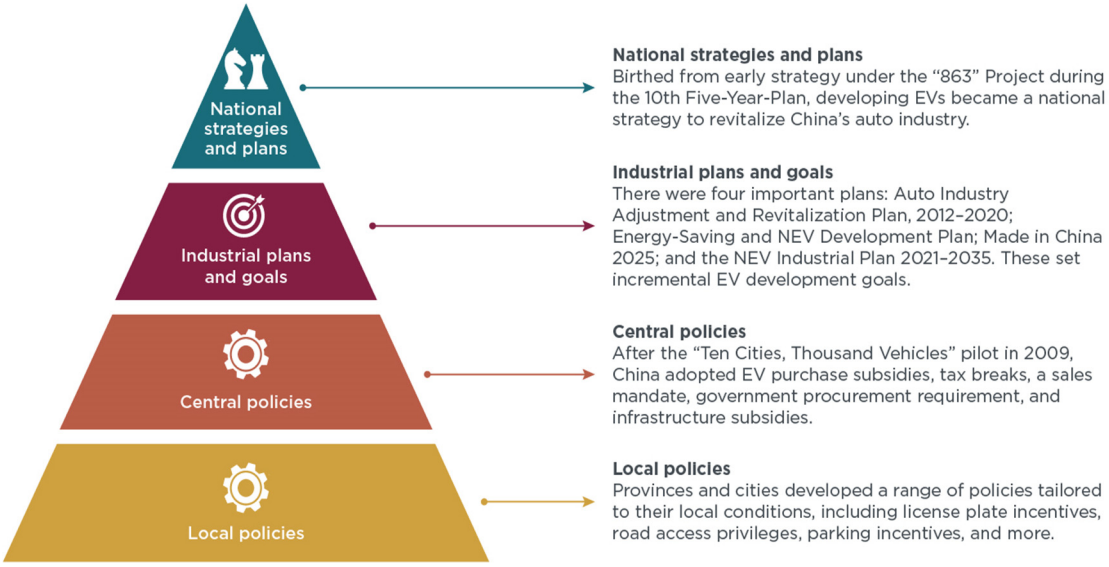


Figure 1. The policy architecture that supports China's EV growth [10].

The high cost of EVs compared to conventional gasoline vehicles, especially in rural areas with lower incomes, remains a barrier to consumer adoption. Additionally, the limited availability of battery materials and lack of standardization in the industry contribute to higher production costs and hinder the growth of the EV market. To mitigate the high cost of EVs, China's government could offer financial incentives, such as tax credits or rebates, and invest in research and development to improve battery technology [11]. The government could also support the development of domestic battery production capabilities and attract foreign companies to establish battery production facilities in China. Meanwhile, the industry could invest in R&D to find alternative battery materials. To address the lack of standardization, the government could establish regulations and standards for EV production and design, and encourage collaboration among carmakers to standardize the industry. A comprehensive and consistent policy on EV development and deployment is necessary to provide certainty for the industry and encourage more investments [12].

Addressing these challenges requires a collaborative effort from the government, private sector, and international community. A comprehensive and coordinated approach is essential to overcome these difficulties and promote the growth of EVs in China and globally.

3. Carbon Saving with the Implementation of EVs

Electric vehicles (EVs) have been touted as a promising solution to reduce carbon emissions in the transportation sector. While it is true that the generation of electricity used to charge EVs can contribute to carbon emissions, their overall impact on the environment is still much lower compared to internal combustion engine vehicles (ICEs) [13]. A study by the International Council on Clean Transportation (ICCT) found that, on average, EVs generate about half the emissions of the average ICE vehicle in Europe, and about one-third the emissions in California [14]. This reduction in emissions is due to the fact that EVs rely solely on electricity for propulsion, and as such, have the potential to emit significantly less carbon emissions when powered by clean electricity sources. The study also projects that the emissions from EVs are likely to decline even further as renewable energy sources become more prevalent in the power mix.

Similarly, the Union of Concerned Scientists (UCS) found that EVs produce about half the global warming emissions of a comparable gasoline-powered vehicle, and in regions with clean electricity, such as California and the Pacific Northwest, an EV produces about one-third the emissions of a comparable gasoline-powered vehicle. It's worth noting that increasing the number of EVs on the road can also help to reduce overall carbon emissions by reducing the demand for gasoline and diesel fuel, which can help to lower the emissions from power plants and refineries [15].

Another benefit of EVs is that they emit significantly less carbon than hybrid vehicles. While hybrids do use some electricity to power their electric motor, they still rely heavily on gasoline for propulsion, and the emissions from the internal combustion engine make up a significant portion of their overall emissions [16]. In contrast, pure EVs rely solely on electricity for propulsion, and thus have the potential to emit significantly less carbon emissions.

It's also important to consider that hybrids, including plug-in hybrid electric vehicles (PHEVs) and extended-range electric vehicles (EREVs), are often considered a transition technology towards full electric vehicles, which are the ultimate goal for achieving zero-emission transportation [17]. In conclusion, while hybrids do offer some benefits in terms of reducing carbon emissions, pure electric vehicles have the potential to be even more effective in reducing carbon emissions, especially when powered by clean electricity sources.

4. Will the ICEV's Replacement by EVs Happen?

The growth of electric vehicles (EVs) is expected to continue in the coming years, but it is unlikely that they will completely replace internal combustion engine vehicles (ICEVs) in the near term. Several factors such as advances in battery technology, cost of EVs, availability of charging infrastructure, and government policies will play a critical role in shaping the future of the automotive industry [18]. Battery technology advancements are likely to lead to lower costs and longer-range EVs, making them more competitive with ICEVs. Government policies, such as tax incentives, regulations, and emission standards, will also have an impact on the market for EVs.

While EVs have the potential to significantly reduce carbon emissions in the transportation sector, their ability to do so will largely depend on the source of electricity used to power them. Several studies and reports provide data on the expected growth of the electric vehicle market and the potential for EVs to reduce carbon emissions. For example, according to a report by the International Energy Agency (IEA), the global electric car fleet is expected to grow from 5 million vehicles in 2017 to 280 million vehicles in 2040, with the share of electric cars in the global car fleet reaching 40% by 2040 [19-20]. A report by the National Renewable Energy Laboratory (NREL) in the United States found that widespread adoption of electric vehicles could reduce greenhouse gas emissions from the transportation sector by 80% by 2050. Additionally, a study by the Union of Concerned Scientists estimated that, on average, electric cars produce less than half the global warming emissions of a typical new gasoline car over their lifetime.

It's worth noting that internal combustion engines will still play a role in certain applications, such as heavy-duty transportation, shipping, and aviation, where electric power is not yet viable. On the

other hand, when it comes to hydrogen fuel cell vehicles, they are still in the early stages of development and not yet widely commercialized, but they have the potential to have zero tailpipe emissions when powered by hydrogen produced from low-carbon sources, such as renewables. In a nutshell, EVs have the potential to significantly reduce carbon emissions compared to traditional gasoline cars, but their exact impact will depend on the source of electricity used for charging [21]. Design students also have an important role to play in reducing carbon emissions by designing lightweight, aerodynamic, and sustainably-manufactured vehicles. Furthermore, hydrogen cars have the potential to have zero tailpipe emissions, but their commercial viability is still in its early stages.

5. Future Trend for EV's Development for Further Reduce Carbon Reduction

The future development trend for electric vehicles (EVs) to reduce carbon emissions can include a focus on using sustainable materials, aerodynamic design, and lightweight construction. For example, using materials such as bamboo or recycled plastic in the manufacturing process can reduce the environmental impact of the vehicle. Additionally, an aerodynamic design can improve the vehicle's energy efficiency, while lightweight construction can reduce the energy required to power the vehicle. Some EV manufacturers are also incorporating solar panels into their designs, which can generate power for the vehicle while it is parked [22]. There are several design and technology solutions that can help to further reduce the carbon emissions of electric vehicles. Some examples include (**Figure 2**):

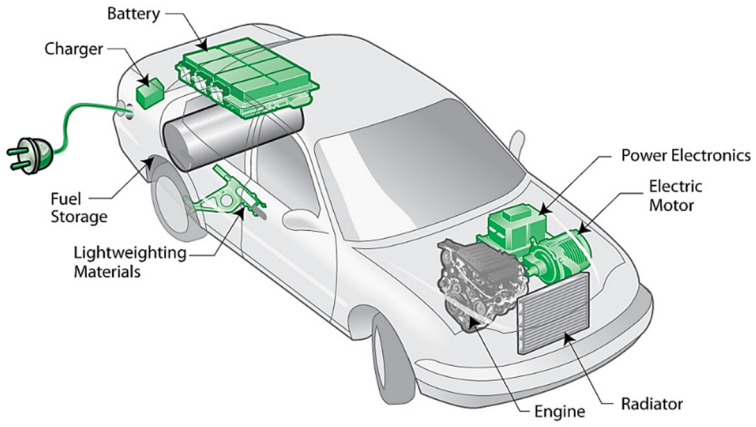


Figure 2. Core technology for the future trend of EV's development [23].

1. Battery electric vehicles (BEVs) that use advanced battery technologies such as solid-state batteries, which have higher energy density and longer lifetimes than traditional lithium-ion batteries.
2. Renewable energy sources to charge their batteries, such as solar panels, wind turbines, or hydroelectric power.
3. Efficient energy and materials, such as those with lightweight materials, aerodynamic designs, and regenerative braking systems.
4. Charging via smart grid technology, which allows for the efficient distribution of electricity to vehicles based on demand and availability.
5. Connected to and communicate with the energy grid and other vehicles, known as V2G (vehicle-to-grid) and V2V (vehicle-to-vehicle) communication, to optimize energy usage.
6. Hydrogen fuel cell, which is used as a fuel source to generate electricity, which can reduce the carbon emissions even further.

It's important to note that the design of a vehicle is just one aspect of reducing carbon emissions, and it must be combined with other efforts such as renewable energy generation and sustainable

transportation infrastructure. According to a study conducted by the International Energy Agency (IEA), the use of electric vehicles (EVs) in China has helped to reduce carbon dioxide (CO_2) emissions [23]. In 2020, EVs in China avoided about 150 million tons of CO_2 emissions, which is equivalent to the total emissions of Greece. This represents a significant reduction in emissions from the transportation sector, which is a major contributor to global CO2 emissions. The production of the electricity used to charge EVs also results in some emissions, so the total emissions savings from EVs depend on the emissions intensity of the electricity mix [24-26]. A study by the Union of Concerned Scientists found that, on average, EVs produce about half the emissions of a similar gas-powered vehicle, when the emissions from electricity production are taken into account. There are several ways to design electric vehicles to reduce their carbon emissions:

1. Using renewable energy sources to power the electric grid: By using renewable energy sources such as solar, wind, and hydroelectric power to generate electricity, the carbon emissions associated with charging electric vehicles can be significantly reduced.
2. Smart charging: Smart charging systems can optimize the charging of electric vehicles to align with periods of low electricity demand and high renewable energy generation. This helps to further reduce the carbon emissions associated with charging electric vehicles.
3. Vehicle-to-grid (V2G) systems: V2G systems allow electric vehicles to provide services to the grid by discharging stored energy during periods of high demand. This helps to reduce the need for fossil-fueled power plants to meet peak demand, which can further reduce carbon emissions [27].
4. Battery recycling: End of life batteries can be recycled to recover valuable materials and reduce the need to extract raw materials, thus reducing the carbon emissions associated with battery production.
5. Lightweight materials and aerodynamic design: Using lightweight materials such as carbon fiber and aluminum, as well as designing vehicles with aerodynamic shapes, can help to reduce the energy consumption and carbon emissions associated with driving electric vehicles [28].

6. Conclusion

Both electric vehicles (EVs) and hydrogen fuel cell vehicles (FCVs) have the potential to play a significant role in reducing transportation-related carbon emissions and addressing climate change. It is likely that both technologies will continue to develop and improve in the future, and it's difficult to predict which one will become more prevalent. However, many experts predict that EV will be more prevalent in the near future, due to the fact that EV technology is more mature and have more charging infrastructure than hydrogen car.

Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Acknowledgments

This research was funded by Enerstay Sustainability Pte Ltd (Singapore) Grant Call (Call 1/2022) _SUST (Project ID CAA-2003), Singapore.

Competing Interests

The authors declare no conflict of interest.

References

[1] S Li, X., & Banister, D. (2018). China's Electric vehicle revolution: policy, planning and progress. Transport Policy, 65, 115-125.

[2] Wang, D., & Dargusch, P. (2019). China's Electric vehicle industry: a review of policy and strategy. Energy Policy, 131, 763-769.

[3] Zhang, Y., & Fan, Y. (2020). Government policies and the development of China's Electric vehicle industry. Renewable and Sustainable Energy Reviews, 138, 110836.

[4] Wu, J., & Wang, D. (2020). China's Electric vehicle market: a review of development, challenges and opportunities. Journal of Cleaner Production, 261, 120809.

[5] Li, Y., & Yang, X. (2021). A review of China's Electric vehicle policy and its influence on technology and market development. Renewable and Sustainable Energy Reviews, 139, 111940.

[6] Chen, Y., & Li, Q. (2019). China's Electric vehicle development and policy. Energy Policy, 131, 570-582. https://doi.org/10.1016/j.enpol.2019.05.037.

[7] Du, X., Wang, D., & Li, X. (2020). Understanding the current status and future prospects of Electric vehicle development in China. Renewable and Sustainable Energy Reviews, 124, 110030. https:// doi.org/ 10. 1016/j.rser.2019.110030.

[8] Li, Q., & Chen, Y. (2018). Electric vehicles in China: current status, challenges and policies. Renewable and Sustainable Energy Reviews, 82, 2663-2676. https://doi.org/10.1016/j.rser.2017.12.005.

[9] Ma, X., & Zeng, X. (2019). Policy support and market penetration of Electric vehicles in China: Evidence from a dynamic generalized method of moments model. Energy Policy, 126, 21-31. https://doi. org/ 10.1016/j.enpol.2018.10.034.

[10] Wang, D., Du, X., & Li, X. (2021). Advancements and challenges in the development of China's Electric vehicle industry. Journal of Cleaner Production, 273, 123239. https://doi.org/ 10.1016/ j. jclepro. 2020. 123239.

[11] Xu, J., & Zhang, Y. (2019). An analysis of the development of Electric vehicles in China. Applied Energy, 238, 16-28. https://doi.org/10.1016/j.apenergy.2018.10.172.

[12] Li, X., Wang, Q., & Chen, W. (2019). Development of Electric vehicles in China: Status, challenges, and policies. Applied Energy, 238, 874-883. https://doi.org/10.1016/j.apenergy.2019.01.165.

[13] Zhang, X., & Chen, Y. (2018). An overview of China's new energy vehicle industry: Status, challenges, and prospects. Renewable and Sustainable Energy Reviews, 82, 3560-3570. https://doi.org/ 10. 1016/ j.rser.2018.03.011.

[14] Lu, Y., & Wang, D. (2020). The development and challenges of China's new energy vehicle industry. Journal of Cleaner Production, 258, 120598. https://doi.org/10.1016/j.jclepro.2019.120598.

[15] He, R., & Fan, Y. (2019). The development and prospect of Electric vehicles in China. Renewable and Sustainable Energy Reviews, 111, 111-121. https://doi.org/10.1016/j.rser.2019.02.077.

[16] Su, Q., & Li, Y. (2020). A review of China's Electric vehicle industry: Status, policies, and challenges. Renewable and Sustainable Energy Reviews, 130, 110321. https://doi.org/10.1016/j.rser.2020.110321.

[17] Zac.H, 2019, Carbon Brief, "Factcheck: How Electric vehicles help to tackle climate change" https:// pubs. acs. org/doi/pdf/10.1021/acs.est.1c06148.

[18] IEA, " Global sales and sales market share of electric cars, 2010-2021", IEA, Parishttps:// www.iea.org/ data-and-statistics/charts/global-sales-and-sales-market-share-of-electric-cars-2010-2 021.

[19] IEA (2021), "Global EV Outlook 2021", IEA, Parishttps://www.iea.org/reports/global-ev-outlook-2021.

[20] Tom. M (2021), "What Are The Different Levels Of Electric vehicle Charging?", Forbes WHEELShttps: //www.forbes.com/wheels/advice/ev-charging-levels/.

[21] Wang, X., & Wang, Q. (2019). China's new energy vehicle industry: Status, challenges, and opportunities. Renewable and Sustainable Energy Reviews, 118, 735-747. https://doi.org/10.1016/j.rser.2019.07.066.

[22] Chen, Y. (2018). The development of electric vehicles in China: Policy, industry, and consumer perspectives. Energy Policy, 117, 36-45. https://doi.org/10.1016/j.enpol.2018.03.007.

[23] Li, Q., & Chen, L. (2019). An analysis of China's new energy vehicle industry development path. Journal of Cleaner Production, 209, 803-811. https://doi.org/10.1016/j.jclepro.2019.01.174.

[24] Su, L., & Liu, Y. (2020). A comparative study of electric vehicle development in China and the United States. Energy Policy, 140, 111915. https://doi.org/10.1016/j.enpol.2020.111915.

[25] Zhang, J., & Liu, X. (2020). Determinants of electric vehicle adoption in China: An empirical study. Transportation Research Part A: Policy and Practice, 138, 242-255. https://doi.org/ 10. 1016/ j. tra. 2020. 06.037.

[26] Liu, J., & Zhang, Y. (2019). The evolution of China's new energy vehicle industry: A review. Renewable and Sustainable Energy Reviews, 111, 297-310. https://doi.org/10.1016/j.rser.2019.03.069.

[27] Liu, Y., & Wang, J. (2021). The impact of government policies on electric vehicle development in China. Energy Policy, 150, 111840. https://doi.org/10.1016/j.enpol.2021.111840.

[28] Zhang, Y., & Li, X. (2022). A review of the development and future prospects of China's electric vehicle charging infrastructure. Applied Energy, 289, 116079. https://doi.org/10.1016/j.apenergy.2022.116079.