

The Need for Transportation Electrification: Root Causes and Limitations

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Abstract. The contradiction between the environment and development is becoming increasingly prominent in the global trend towards cleaner, lower carbon, and smarter energy sources, leading to people's critical thinking about the transport sector, one of the most significant areas. Transportation electrification is giving rise to Net Zero development. In this context, this article focuses on the need to electrify transportation in this emerging trend while pointing out some key problems along the way. Through a systematic analysis of environmental and technological aspects, the article analyzes both environmental and technical aspects and also finds that the electrification of transport is an important initiative to reconcile environmental and resource conflicts. Moreover, it has now grown to a scale beginning to contribute to solving environmental problems. At the same time, the analysis shows that there are still some difficulties on the road to transportation electrification in terms of energy footprint and infrastructure. The related opportunities and challenges are also highlighted.

Keywords: Transportation, electrification, renewable energy, electric vehicle.

1. Introduction

Global warming is becoming increasingly prominent in today's world, leading to rising sea levels, damage to marine ecosystems and more natural disasters, among other problems. In 2020, China proposed the concept of carbon neutrality at the 75th session of the United Nations General Assembly, and now all countries worldwide are making continuous efforts to achieve carbon neutrality. In this context, the global trend towards cleaner, low-carbon and intelligent energy has become a trend. As a very important and widely used energy source, the development of the electrical industry has become an important direction for the current change in energy technology, which is of great significance for China and the world to realize the energy transition in the new era.

The transport sector is one of the most important areas for the application of electrical energy, as the emissions from fuel cars are causing huge pollution, which is also an important cause of the greenhouse effect, and the study of transport electrification is of great significance to alleviate the global warming problem. In modern society, the electrification rate of transportation is getting higher and higher, the range of electric vehicles is getting better and better, the service life of car batteries is getting longer and longer, and people's research on transportation electrification is getting deeper and deeper. The technology of electrification is getting increasingly mature, but there are some problems with the realization of transportation electrification. This report builds on existing research to further explore transport electrification's needs and limitations.

This report first explains the need to electrify transport nowadays from the perspective of global warming, followed by some of the more mature technologies in the field of transport electrification and the superiority of electricity over hydrogen to illustrate the huge potential of transport electrification. In terms of the limitations of transport electrification, the paper looks at three aspects of charging stations, energy footprints and battery technology to illustrate some of the problems that still exist in electrifying transport today.

2. Reasons

2.1. Global warming

Global warming is becoming increasingly prominent, with the world facing the hottest temperatures on record this year, even in the Arctic, where people are wearing short sleeves [1]. Compared to the global eve of industrialization at the beginning of the 20th century, the average surface temperature today is at least 1.1°C warmer, polar glaciers are melting dramatically, with over 400 billion tons disappearing each year, and global sea levels are now rising by an average of 34 mm per year.

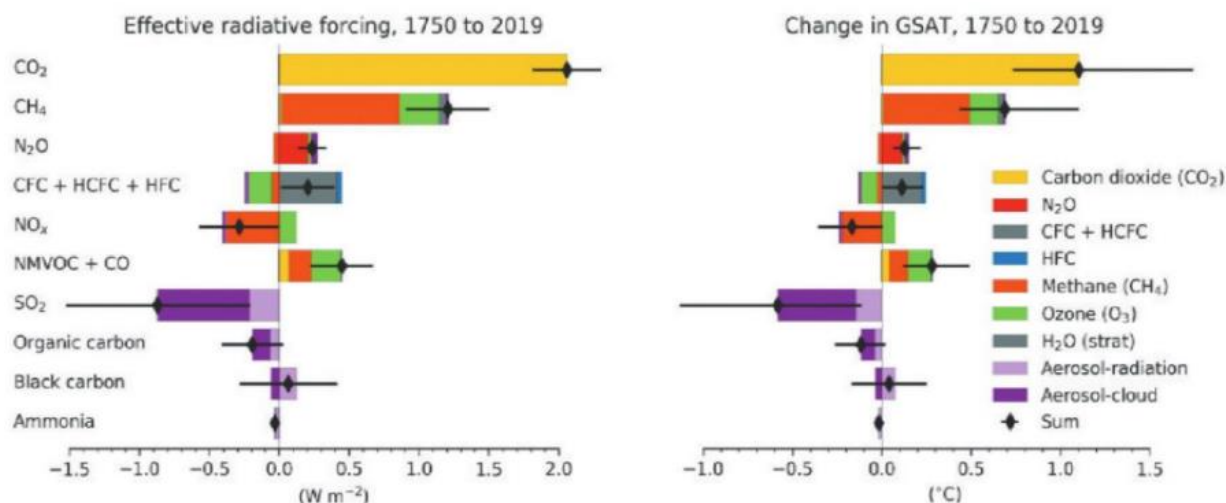


Figure 1. Effective radiative forcing from changes in emissions of various chemical substances from 1750 to 2019 and the impact relative to global mean surface temperature [2].

This is the effective radiative forcing from changes in emissions of various chemicals from 1750 to 2019 and the impact relative to the global average surface temperature, and we can see that carbon emissions are a big influence. Moreover, this transport plays a major role in achieving the carbon neutrality target. According to the World Resources Institute, global greenhouse gas emissions increased by 51.9 percent from 1990 to 2017, with emissions from the transport sector growing by 75 percent [3]. With an increased number of cars nowadays, the transport sector has become an important source of energy consumption and pollution emissions for all countries. In China, from 11 million cars in 2001 to 280 million in 2020, car ownership is growing yearly, and the growth rate is getting faster. However, by the end of June 2022, the country's motor vehicle fleet reached 406 million units, of which 310 million were cars and 10.1 million were new energy vehicles, accounting for only 3.23% of the total number of cars [4]. Transport emissions are still significant, and to achieve our goal of carbon neutrality, one should continue to promote the electrification of transport to alleviate our environmental problems (Figure 1).

2.2. The development of transport electrification

2.2.1. Electric vehicle technology

From 1834, when the American Tomas Davenport invented the first DC motor-driven electric car to the current Tesla model 3, electric car technology has advanced much. The latest Tesla Model 3 now has a range of 675 km on a single charge and can be replenished with a range of 279 km on a 15 min charge at a Supercharger station, all technologies that go some way to alleviating people's anxiety about the range of electric vehicles. There is also the 4680 batteries from Tesla, Amprius 100% Silicon Nanowires Anode Material. Tesla's 4680 battery is five times more energy dense than the current mainstream ternary lithium battery, with a 16% increase in range, a six-fold increase in output power, and a 14% reduction in production costs. The Amprius 100% Silicon Nanowires battery has an energy density of 450 Wh/kg and can be charged and discharged up to 1400 times. These

technological innovations have improved the performance of pure electric vehicles, allowing us to experience the superiority of electric vehicle performance nowadays and increasing confidence in the road to the electrification of transport.

2.2.2. Electric vehicle technology

The development of electric vehicles has been very rapid recently, and according to statistics, the number of electric vehicles in China will exceed 10 million by 2022. However, there have been problems with the range of electric vehicles compared to traditional fuel vehicles, and electrified road systems have been created in this context. Electrified road systems are much like trams in that they connect the road to the grid, and once a car is connected to the road, it will also be connected to that. ERS systems can shift road transport from reliance on fossil fuels to renewable energy sources [5]. With this system, we can provide a continuous supply of electricity to the electric vehicles driving them, which can largely solve the problem of electric vehicle range. Electrified roads are now available in more mature technologies, mainly overhead (a), rail (b), and induction (c) technologies (Figure 2).

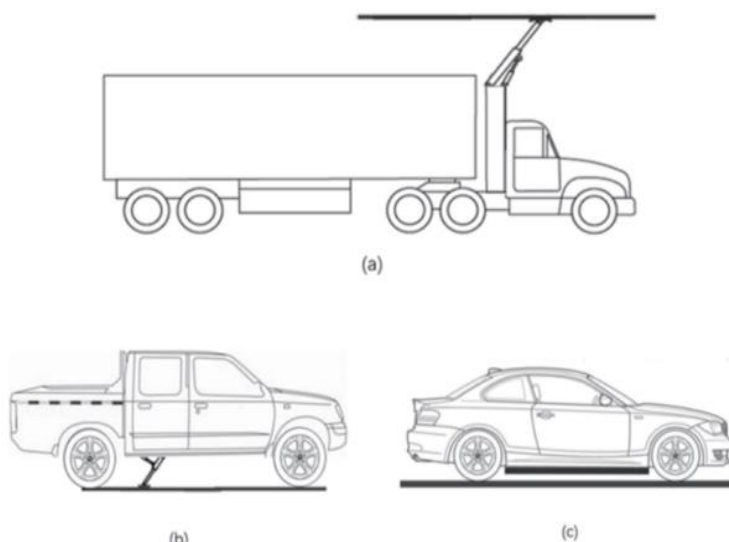


Figure 2. Diagram of the three different technical implementations [5].

(a) Overhead conductive technology: in the figure, the vehicle is then connected to the grid directly via a pantograph with a conductive wire. The advantage of this technology is that it is very flexible and well-established, but it also has the obvious disadvantage that it is only suitable for trucks and buses. (b) As seen in the pictures, rail-based technology lays conductive tracks on the road, and the vehicle is connected by a robotic arm that transmits electricity from the tracks to the vehicle. (c) Inductive technology is based on wireless electricity transmission via an alternating magnetic field between the ERS system and the vehicle. The vehicle pictured here is charged by this technology, which minimizes vehicle movement.

2.2.3. Electrified railway

Electrified railways are also an especially important part of transport electrification nowadays because, in addition to roads, rail transport is also a particularly important part of the transport. Railway transport involves long-distance power supply, and the leading solution for long-distance power supply is the cable + AT power supply solution.

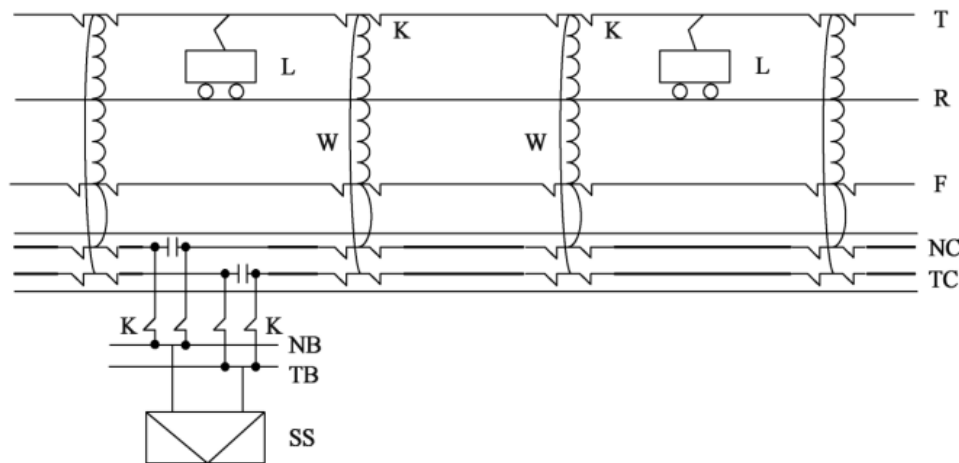


Figure 3. Cable + AT power supply schematic [6].

The diagram on the left shows the schematic diagram of this power supply method (Figure 3). The cable + AT power supply method has a smaller traction network equivalent impedance and lower voltage losses, and the power supply distance is greatly extended compared to the AT power supply method, which can reduce the number of lines electrical split phases and is conducive to the development of electrified railways [6].

2.3. Limitations of hydrogen energy technology

Hydrogen fuel cells have been successfully used in aerospace applications since the 1960s and have many advantages [7], such as no pollution, high energy conversion efficiency, and simple reactions. However, hydrogen energy technology has not been widely promoted because it has many limitations compared to electricity. The first is the problem of carbon monoxide poisoning. Hydrogen comes from steam reforming and water gas conversion reactions of hydrocarbons such as methanol and natural gas. The resulting hydrogen usually contains 0.5% to 2% carbon monoxide, which can poison the electrodes and reduce their performance and lifetime [8]. The second is that the current hydrogen storage technology is not yet mature, and the cost of storing hydrogen is huge and very unstable, with certain safety issues. The third is that hydrogen energy is too expensive, and the cost of extracting hydrogen is so high that many people cannot afford to pay such a high amount. Therefore, hydrogen energy is not yet widespread. Its high cost and the safety risks associated with its immature technology are something that we cannot overcome yet, and it is not suitable to be the new energy source that we are using on a large scale compared to electricity, which shows the necessity and superiority of electrifying our transport now.

3. Limitations

3.1. Charging post issues

With an increased number of people choosing electric vehicles, charging is becoming a critical issue, and the difficulty of charging is becoming an increasingly prominent problem, with many electric vehicle owners now facing difficulties in charging because they cannot find a charging post.

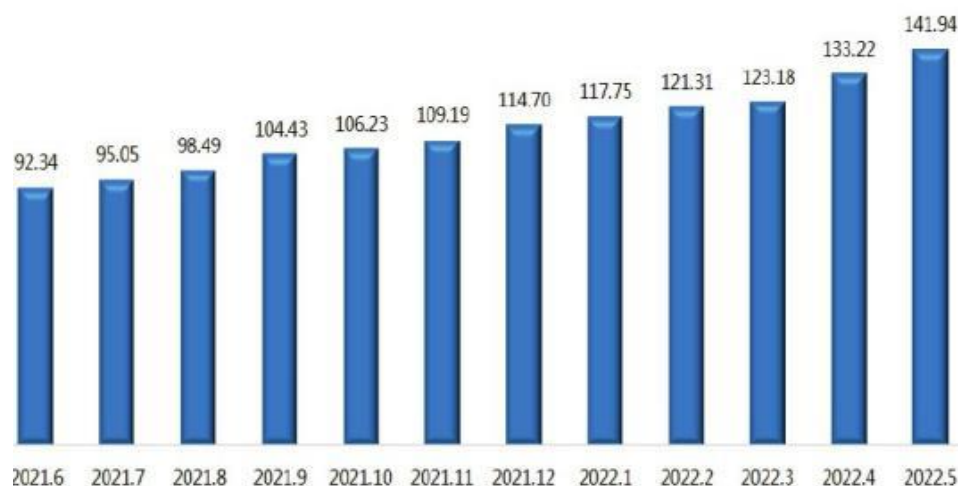


Figure 4. Public category charging post holdings in the last 12 months (in 10,000 units) [9].

By the end of May 2022, the cumulative number of charging infrastructure in China was 3,581,000 units, of which 1,149,400 were public charging piles, while the number of electric vehicles in China has exceeded the 10 million marks, and the domestic vehicle-pile ratio for new energy vehicles is about 2.5:1, i.e., each charging pile serves 2.5 vehicles, far below the construction target of 1:1 (Figure 4) [9].

On the other hand, the layout of charging piles is not reasonable, with queues for charging in some hotspots and charging piles lying idle for long periods in some areas [10]. In addition, due to the lack of unified standards, some operating companies' level of interconnection and interoperability is low, and the charging pile interfaces are incompatible, resulting in a low utilization rate of charging piles. These are some of the problems with charging piles now. Although many people have bought electric cars, they still need to worry about their charging problems. They cannot find charging piles to charge; they find charging piles, but the piles are broken, and there are some areas where the demand for charging piles is not big, but there are still many charging piles, which leads to the situation that there are idle charging piles. Therefore, the problem of charging posts is now an important issue in the electrification of our transport.

3.2. Energy footprint

When talking about the energy footprint, which is where our current limitations in achieving transport electrification lie, the essay compares the energy consumption of fuel-fired and purely electric vehicles in the three stages of raw material production, vehicle manufacturing, and vehicle use from the perspective of the vehicle life cycle [11], in terms of raw materials, batteries require raw materials such as copper, lithium, cobalt, and nickel, which are concentrated in places such as the Congo, Chile, and Indonesia. It also generates carbon emissions during the transportation of raw materials, estimated at 182 million tonnes per year from container ships.

The energy consumption in production is similar, but pure electric cars have batteries, which require additional energy consumption. This energy consumption is also relatively large; from this perspective, analysis of pure electric cars may not save energy but also consume more energy. Finally, talking about the use of cars, the most discussed issue is the source of electricity and oil. Although electric vehicles are emission-free, their electricity is not entirely environmentally friendly, which also considers the country's power supply model. In Switzerland, for example, electricity is generated mainly by nuclear power and hydroelectricity. This electricity supply mode allows the country to achieve a 100% carbon reduction efficiency. However, China's power generation structure is still dominated by thermal power, accounting for 71.2% of the total, which means that without reaching a certain mileage (around 30,000 km), pure electric cars are less environmentally friendly than fuel cars because the process of thermal power generation generates huge carbon emissions. Many parts of the world are still dominated by thermal power, and very few countries like Switzerland can reduce

their carbon footprint so efficiently, so there is a question mark over the environmental friendliness of pure electric vehicles. Considering the above three aspects, electrification of transport still has many limitations, and it is still a question of whether electrification is environmentally friendly from the perspective of energy footprint.

3.3. Environmental (temperature and altitude) effects on the battery

Regarding temperature, the batteries in pure electric vehicles are now mainly lithium batteries, but in low-temperature conditions, the electrochemical performance of lithium-ion batteries is drastically reduced. Firstly, it will cause the battery to take even longer to charge. The charging time at low temperatures (-10 degrees Celsius) will be 32% longer than at room temperature because charging can only occur when the cells are heated to a temperature suitable for charging. This process will not only take time but also consume the power of the power battery system, causing a huge problem for the normal charging of the electric vehicle in a low-temperature environment, the charging efficiency of the electric vehicle is reduced.

Secondly, the range will also be reduced because, in low-temperature conditions (-10°C), the capacity and operating voltage of the commonly used lithium-ion battery for electric vehicles will be significantly reduced. The range under the same working conditions is only 68% at room temperature, and the energy consumption per 100 kilometers is also 134% of that at room temperature. The difference brought about by this data is huge, and the range is much reduced compared to the conditions at room temperature. In low-temperature conditions, the range of the car is a particularly important issue, which is related to the safety of people. People's ability to move in a low-temperature environment is extremely poor. They need the car to get through this environment. In a low-temperature environment, the range of the car is reduced, resulting in the driver being trapped in that environment. The safety risks behind its existence are also something to keep an eye on.

As some areas of the country are at high altitudes and driving at high altitudes is a problem that cannot be avoided, this is also an especially important issue. As the altitude rises, the atmospheric pressure drops significantly, and this drop in atmospheric pressure can have an impact on the performance of the battery. As the altitude rises, the temperature of the battery discharge will increase, and this change may cause the battery performance to become unstable, thus causing some safety problems. Furthermore, as the temperature of the battery rises to a certain level, the internal pressure of the battery will also rise, and this change will cause the explosion-proof threshold to open; in the process, the battery will continue to do work externally, which will lead to a sudden drop in temperature, around 4000 m, the explosion-proof threshold of the battery will open at a relatively low temperature, which will lead to many safety problems. These problems may pose a safety risk to people driving at high altitudes, but they also exist now, which limit the development of more electrified transport and are issues that need to be urgently addressed.

4. Conclusion

This paper examines the need for and limitations of transport electrification. In terms of necessity, the importance of transport electrification in mitigating the greenhouse effect, the fact that there are already some mature technologies for electrification in the transport sector, and the huge advantages of electricity by illustrating the problems of new energy sources, such as hydrogen, compared to electricity, are explained. Regarding limitations, the number and distribution of charging posts are uneven, the total carbon energy footprint of purely electric vehicles is still large, and there are still problems with current battery technology that need to be improved. It is clear from the research that electrification in transport is now taking place on a certain scale and that a wide range of electrification technologies have been applied to transport, bringing great convenience to people and alleviating global warming, all of which illustrate the superiority and enormous, However, transport electrification also faces some problems, mainly in terms of inconvenient charging, high energy

consumption in electricity production and batteries being affected by harsh environments, which are issues we now need to break through.

Electrification of transport is now a very important and popular topic, providing a very good way to achieve the goal of carbon neutrality and alleviating energy pressure. It is an inevitable product of the current pressure on resources and the environment, but it also has a superiority that other energy sources do not have. This path has now also evolved. Technology is becoming increasingly sophisticated, the benefits are becoming more and more apparent, and with electrification becoming more widespread, things are getting better and better. However, at the same time, there are also some problems on the road of electrification development, so in the future, people need to focus their research angle more on the range of electric vehicles, environmental issues and technical issues so that electrification technology can better serve humankind.

References

- [1] Hao Y 2022 Explor. Nat. 7 30 - 34.
- [2] Fang X, Lin W and Tao H 2021 Jiangsu J. Sci. Tech. A 12 000376.
- [3] Zhang C and Li M 2022 WTC 966 - 968.
- [4] Zheng X 2022 Auto. Rev. 8 105 - 107.
- [5] Xia Y 2021 J. New. Ind. 8 43 - 44.
- [6] Ren Z, Xie S and Ci K 2022 WTC 245 - 251.
- [7] Zhang G, Yang Y and Liu F 2018 J. Chongqing Univ. Technol., Nat. Sci. 12 21 - 30.
- [8] Tong L and Li W 2019 Auto. D. Ser. 3 72 - 73.
- [9] Zheng X 2022 Auto. Rev. 2 116 - 117.
- [10] Zhou J and Zhang X 2022 J. Econ. Ob. 13.
- [11] Luo X and Huang I 2014 J. Chin. Popul. Resour. 9 84 - 90.