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# The application and prospect of electrification in transportation

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**Abstract.** Human technology has developed very rapidly in just a few hundred years, especially in the development of transportation and travel methods. From the very beginning, the emergence of the steam engine, to the widespread use of internal combustion engines based on fossil fuel energy, and now the popularity of electric motors. This development process not only shows the rapid development of human science and technology, but also shows people's efforts in terms of fast, convenient, rapid and energy-saving transportation. Especially in the combination of electricity and people's transportation modes: from the very beginning of electric locomotives to electric vehicles with low prices and low maintenance costs, electricity is more and more widely used in traffic life. This study will focus on the production of electricity and the drawbacks in the process of electricity production, and the mainstream use of electricity in transportation. Finally, the future of transportation electrification is prospected and considered appropriately.

**Keywords:** Transportation Electrification, Electric Vehicles, Electric Motor.

## 1. Introduction

Transportation electrification refers to the process of transitioning the transportation sector, particularly vehicles, from conventional internal combustion engines (ICEs) to electric power [1]. This involves the adoption and integration of electric vehicles (EVs) and the establishment of the necessary infrastructure to support their widespread use.

One of the primary motivations behind transportation electrification is to reduce greenhouse gas emissions and combat climate change. Electric vehicles produce zero tailpipe emissions, which significantly improves air quality and reduces the carbon footprint associated with transportation [2]. Additionally, electrification can reduce the frequency of fossil fuel use and make energy use more stable and sustainable.

The future development of transportation electrification is promising. As technology advances and economies of scale improve, EVs are becoming more affordable and accessible to a wider range of consumers [3]. Governments and regulatory bodies are also supporting this transition through incentives, subsidies, and the implementation of stricter emission standards.

One key area of future development is the expansion of charging infrastructure. The extensive construction of charging piles is complementary to the widespread use and popularity of electric vehicles.

Another important aspect of transportation electrification is the advancement of battery technology. Improvements in battery energy density, charging speed, and longevity will address the limitations of current EVs, such as limited range and longer charging times. Research and development efforts are focused on developing more efficient and cost-effective batteries, including solid-state and next-generation lithium-ion batteries.

Furthermore, EVs integrated with renewable energy sources like solar and wind are becoming more popular. EVs can function as mobile energy storage devices, facilitating the seamless incorporation of intermittent renewable energy into the grid [6]. This is achieved through vehicle-to-grid (V2G) technology, which enables two-way energy flow between EVs and the power grid. V2G reduces peak demand and optimizes energy usage.

## 2. The spread of electrification of transport

With the development of science and technology in the world, the use of electricity in transportation is becoming more and more frequent. The following subsections take China as an example to briefly introduce the reasons for transportation electrification.

### *2.1. Reasons for electrification in transportation*

There are several reasons behind China's push for electrification in transportation. Firstly, environmental protection and emission reduction targets play a crucial role. As one of the largest greenhouse gas emitters globally, China faces severe air pollution and carbon emissions issues. The transportation sector holds significant responsibility in this regard, as conventional fuel-powered vehicles contribute to substantial tailpipe emissions. By promoting electrification in transportation, China can effectively reduce exhaust emissions and carbon footprints, improve air quality, and achieve its environmental protection and emission reduction goals.

Secondly, resource security and energy transition are also driving factors for China's push towards electrification in transportation. China relies heavily on imported petroleum and natural gas, making it vulnerable to supply fluctuations and price volatility. By promoting electrification, China can reduce its dependence on imported energy, enhance energy security, and accelerate the transition towards cleaner, renewable energy sources.

Furthermore, technological advancements and industrial upgrades have expedited the development of electrification in China's transportation sector. With the continuous maturity and progress of electric vehicle technology, declining battery costs, improved performance, extended range, and faster charging speeds have been achieved. As one of the world's largest automotive markets, China's active promotion of electrification helps stimulate the growth of the domestic electric vehicle industry and enhances the country's competitiveness in the field of new energy vehicles.

Simultaneously, urban congestion and traffic efficiency issues have also driven the development of electrification in China's transportation sector. Chinese cities face severe traffic congestion problems that not only affect people's travel efficiency but also have negative impacts on the environment and public health. The widespread adoption of electric vehicles can reduce traffic emissions and noise pollution, thereby improving the travel environment for people. Additionally, the use of electric public transportation contributes to enhancing urban transportation efficiency and optimizing the city's overall transportation system.

Lastly, government support and policies have played a vital role in driving electrification in China's transportation sector. The government has implemented a series of policies to support electric vehicle development, including purchase subsidies, free parking, and the construction of charging infrastructure. These policies and measures encourage domestic consumers to purchase and use electric vehicles, providing robust support for the electric vehicle market.

In summary, the reasons behind China's push for electrification in transportation involve various aspects such as environmental protection, resource security, industrial upgrades, traffic efficiency, and energy transition. Through government policy support and technological advancements, China is achieving a sustainable transformation in the transportation sector, providing cleaner, more efficient, and convenient modes of travel for its people, and contributing to the vision of sustainable development

Because China is a developing country, if the application of transportation electrification can be widely popularized in China, it proves that the popularity of this technology is widespread in the world.

### *2.2. Limitations*

Although the advantages of transportation electrification are many, the technology also has many limitations.

Firstly, the electrification of transportation involves high infrastructure construction costs. The large-scale deployment of charging infrastructure requires significant financial investments, and it may be constrained by land and resource availability. Additionally, the layout and distribution of charging facilities, such as charging stations and charging points, need to be planned to meet the charging demands of electric vehicles.

Secondly, power supply and energy transition are critical aspects in achieving transportation electrification. Meeting the charging demands of electric vehicles requires a substantial power supply. However, in certain areas, there may be insufficient power supply or an inadequate power distribution system, which hinders the requirements of transportation electrification. Moreover, the production and distribution of electricity also need to undergo an energy transition from traditional fossil fuels to renewable sources to ensure the environmental friendliness of the power source for electric vehicles.

Thirdly, charging efficiency and speed are factors limiting the development of transportation electrification. Compared to traditional fuel-powered vehicles, the charging process of electric vehicles takes longer, which may restrict their widespread use in long-distance travel and high-demand scenarios.

Fourthly, limited driving range and scarce charging infrastructure are also limiting factors. Despite continuous improvements in battery technology, current electric vehicles still face limitations in terms of driving range, unable to match the long-distance capabilities of traditional fuel-powered vehicles. Additionally, the relative scarcity of charging infrastructure restricts long-distance travel and cross-regional usage of electric vehicles.

Technical and innovation challenges are another significant factor that transportation electrification needs to overcome. The technologies of electric vehicles and charging facilities are still evolving, requiring solutions to challenges such as battery durability, cost-effectiveness, and safety. Furthermore, the smartness and interoperability of charging infrastructure are also technical issues that need to be addressed.

Lastly, consumer acceptance and habit changes can also impact the development of transportation electrification. Shifting to transportation electrification requires people to change their traditional driving habits and adopt new electric vehicles and charging habits. The speed at which consumers accept and adapt to these changes will also directly affect the pace of transportation electrification.

In conclusion, transportation electrification faces various limiting factors, including high infrastructure construction costs, power supply and energy transition, charging efficiency and speed, limited driving range and scarce charging infrastructure, technical and innovation challenges, and consumer acceptance and habit changes. Overcoming these limiting factors requires comprehensive considerations of economic, technological, policy, and societal aspects to drive further development of transportation electrification.

## 3. The world's dominant way of producing electricity

The electric energy required for transportation electrification in the process of production for the environment is also small pollution. although there are many ways to generate electricity, no matter which way for the environment, it is a link that cannot be ignored.

The above mentioned are some of the problems arising from the macro perspective of transportation electrification. The following will introduce the limiting factors of transportation electrification from a micro perspective, such as the production mode and process of energy, and the use of energy.

There are several common ways to produce electrical energy. They include:

1. Thermal power generation: This method involves burning fossil fuels such as coal, natural gas, or oil to generate steam, which then drives a turbine generator to produce electricity.

2. Nuclear power generation: Nuclear energy is harnessed through nuclear reactions, either fission or fusion, in a reactor to produce heat. The heat is then used to generate steam, which powers a turbine generator.

3. Hydroelectric power generation: This method harnesses the kinetic energy of flowing water to drive turbines, which in turn generate electricity. Hydroelectric power is one of the most widely used renewable energy sources.

4. Wind power generation: Wind energy is converted into electricity using wind turbines. The rotational motion of the turbine is converted into electrical energy by a generator.

5. Solar power generation: Solar energy is directly converted into electricity using photovoltaic (PV) panels or concentrated solar power (CSP) technology, which captures and converts sunlight into electricity.

6. Biomass power generation: Biomass, such as wood, agricultural residues, or animal waste, is burned or fermented to produce heat, which is then used to generate steam and drive a generator.

7. Geothermal power generation: Geothermal energy utilizes heat from beneath the Earth's surface to generate steam, which drives a turbine generator to produce electricity.

These are some commonly used methods for producing electrical energy. Each method has its own characteristics, advantages, and suitability for different conditions. The choice of energy production method depends on factors such as geographic location, cost-effectiveness, environmental impact, and sustainability.

When electricity is generated, there needs to be a machine to convert it into other forms of energy, so that it can be used in traffic, and this machine is the brush motor and the brushless motor. The following is the introduction of brush motor and brushless motor.

### *3.1. Brushless motor*

Figure 1 shows a schematic diagram of a brushless motor.

**Figure 1.** Schematic diagram of a brushless motor Source link: https://baike.so.com/doc/6069728-6282798.html).

A brushless motor (BLDC motor), also known as an electronically commutated motor, is an electric motor that achieves rotor commutation through an electronic controller instead of a traditional mechanical commutation system. It has the working principles:

The working principle of a brushless motor involves stator windings generating a magnetic field, and a rotor with permanent magnets producing its own magnetic field. The electronic controller receives feedback from rotor position sensors (typically Hall effect sensors) and precisely controls the current flow through the stator windings to maintain rotor stability [5]. By adjusting the output signals of the electronic controller based on the rotor position and speed information, the brushless motor achieves current inversion and commutation, thereby driving the rotor rotation.

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Brushless motors offer excellent speed control performance and torque output control due to precise electronic control [6]. By varying the output signals of the electronic controller, the brushless motor's speed and torque can be precisely regulated. This precise control makes brushless motors widely used in various fields, including power tools, electric vehicles, industrial automation, robotics, and household appliances.

In summary, brushless motors, with their high efficiency, high power density, wide speed range, and high reliability, have great potential and have become a significant direction in motor technology development [7]. They enable efficient energy conversion, and effective use of energy, and contribute to sustainable development and environmental preservation.

### *3.2. Brushed motor*

Figure 2 shows a schematic diagram of a brushed motor.

**Figure 2.** Schematic diagram of a brushed motor (Source link: https://baike.so.com/doc/5954033-6166976.html).

A brushed motor consists of a stator and a rotating rotor. The stator contains windings that generate a magnetic field when current flows through them. The rotor, either with permanent magnets or its own windings, interacts with the magnetic field generated by the stator, resulting in torque production. To achieve rotor rotation, brushed motors employ a mechanical commutation system.

The mechanical commutation system comprises brushes and a commutator. The brushes, in contact with the windings, make contact with conductive segments on the commutator. As the current flows through the windings, the contact points between the brushes and the commutator change, altering the direction of the current and achieving rotor direction reversal.

The mechanical commutation in brushed motors introduces some limitations and issues, such as friction, wear, and brush lifespan. However, brushed motors still possess advantages in specific applications, particularly those with lower costs and simpler operating environments.

In summary, a brushed motor is an electric motor that uses a mechanical commutation system for rotor switching [8]. It features a relatively simple structure and finds applicability in cost-sensitive fields. While brushed motors have certain limitations, they still offer advantages in suitable application environments.

## 4. Applications of transportation electrification

Through the brief introduction above, several applications of traffic electrification are summarized.

1. Electric Trains: Electric trains are one of the most common applications of transport electrification. Electric power is transmitted to the train from an external power supply system to drive the train. Electric trains are typically powered through overhead contact wires or a third rail [9].

2. Trams: Trams, also known as streetcars, are another common application of transport electrification. Trams are powered by connecting to an electric power system through overhead contact wires or a collecting device. Trams play a significant role in urban public transportation.

3. Subways: Subway systems typically use AC power, transmitting electric energy to subway vehicles through power rails or third rail systems to provide propulsion.

4. Electric Buses: Electric buses are emerging applications of urban transport electrification. Electric buses store electrical energy in batteries or supercapacitors and are charged through external charging facilities or wireless charging technology to meet the power demands of the vehicles.

5. Electric Vehicle Charging Stations: Transport electrification also includes the establishment and operation of electric vehicle charging infrastructure. Charging stations are deployed and equipped to offer convenient charging services for electric vehicles, promoting their widespread adoption and development.

6. Bicycle Charging Stations: In some cities, transport electrification includes the installation of bicycle charging stations. These charging stations allow cyclists to generate electricity through pedal power, storing the generated energy to be used by the city's power grid.

The applications of transport electrification help reduce reliance on fossil fuels, decrease emissions and noise, and enhance the efficiency and sustainability of transportation systems [10]. With the continuous development of clean energy and electric mobility, transport electrification will continue to play a vital role in the future

## 5. Conclusion

This paper introduces the production mode of electric energy and its drawbacks in production and introduces the mainstream use mode of electric energy in traffic electrification. Can see that if we blindly rely on fossil fuels to meet people's growing demand for transportation, it will cause more serious and irreversible damage to the environment in the near future. In addition, fossil fuels are non-renewable resources, so excessive exploitation of ecological damage is more serious. In order to achieve the purpose of transportation on the premise of protecting the environment, people use electricity, and more and more vehicles replace the internal combustion engine system with electric power system, so that they can meet the same travel demand. However, in the face of such a huge scale of electricity demand, the process of electricity production will still pollute the environment, but this is inevitable. To reduce the pollution to the environment, with the progress of science and technology, people will control the pollution within the ability of the earth to adjust, and achieve a dynamic balance.

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