# Environmental Impacts of Transportation Electrification: A Comparative Analysis of Energy Efficiency and Pollution Reduction

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**Abstract.** The growing demand for energy has positioned transportation as a major driver of global energy consumption and environmental pollution. With increasing concerns about climate change, electrifying transportation has gained momentum as a critical solution for reducing emissions and improving energy efficiency. This paper focuses on assessing the environmental impact of transportation electrification by comparing the energy consumption and pollution levels of electrified systems with those of conventional transportation methods. The analysis is based on two major aspects: the utilization of electric power in various modes of transport and the transportation of electric power within the infrastructure. By reviewing recent data and studies, this paper demonstrates that electrified transportation significantly reduces both greenhouse gas emissions and other harmful pollutants while simultaneously improving energy conservation. The findings unveil the importance of adopting electrification to mitigate the negative environmental effects of the current transportation system. Additionally, the study suggests that electrifying transportation contributes to long-term sustainability goals, presenting a viable path forward in addressing environmental challenges and supporting global efforts toward a cleaner, more efficient future.

**Keywords:** Transportation electrification; environmental impacts; energy efficiency; pollution reduction.

## 1. Introduction

Nowadays, global energy demand is rising rapidly, from 41814 TWh in 1960 to 179819 TWh [1]. With the increase in global energy consumption, the environmental problems it produces become more prominent, such as environmental pollution intensification, resource shortage, increasing pressure on economic growth, etc. Current transportation relies largely on internal combustion engines that run on fossil fuels, and this accounts for about a third of energy consumption. Electrification of transport can effectively reduce the direct use of fossil fuels. In addition, it has higher energy efficiency and can use resources more efficiently. The process of electrifying transportation will provide new growth engines for the economy through the popularization of new technologies and so on. To reduce environmental pollution, the world's energy consumption structure is also changing to be more environmentally sustainable. From 6.45% in 1965 to 14.56%, the share of renewable energy is constantly increasing [1]. The electrification of transport will further stimulate the development of renewable energy. In the face of increasing demand for transport, the world should adopt a less carbon-intensive approach. The electrification of transportation can effectively facilitate the decentralization of diverse modes of transportation [2]. The world could, in turn, attain carbon neutrality by the year 2050.

This paper aims to provide a comprehensive analysis of the environmental impact of transportation electrification, discuss the transformation and optimization of the power grid and other facilities by transportation electrification, and provide some outlooks on the future of electrical transportation.

## 2. The Advantages of Electrified Transportation

### 2.1. Reduce Carbon Emissions

Electrification of transport will increase the use of electric vehicles (EVs). The popularization of EVs will effectively reduce carbon emissions. The case studies conducted in the Beijing-Tianjin-Hebei region demonstrate that achieving a 100% EV penetration by 2050 could result in energy savings and a reduction of at least 11% in $CO_2$ emissions, all without necessitating an increase in renewable energy capacity [3]. Over the life cycle, EVs also have a lower carbon footprint than gasoline vehicles. When powered by the standard European electricity supply, assuming a vehicle service life of 150,000 km, EVs exhibit a reduction in Global Warming Potential ranging from 20 to 24 percent compared to petrol Internal Combustion Engine Vehicles (ICEV) and from 10 to 14 percent compared to diesel ICEVs [4]. The longer the journey, the more obvious the advantages of EVs. When combined with low-carbon green energy, the carbon footprint of EVs becomes even lower. The adoption of EVs in electrified transportation has the potential to significantly mitigate carbon emissions.

### 2.2. Raise Energy Utilization Efficiency

EVs are more energy efficient than gas-powered vehicles. As shown in Fig. 1, assuming a total energy supply of 1, the utilization efficiency of fuel vehicles is about 16% to 24%, and that of EVs is about 74% to 81% [5]. Because the internal combustion engine generates a lot of waste heat during operation, most of the energy of the fuel vehicle is wasted. Electric cars, on the other hand, use electric motors to drive them and lose less energy in the process of energy conversion.

As shown in Fig. 2, EVs are more energy efficient when using electricity generated by solar or wind systems. Most electric vehicles are equipped with energy recovery systems, which can also improve energy efficiency. With higher energy utilization efficiency, electrification of transport can achieve greater results with less resource consumption.

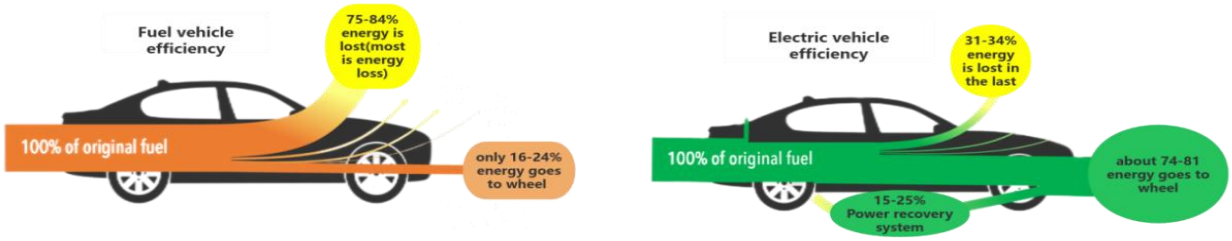


**Fig. 1** Efficiency comparison of fuel and EVs [6]

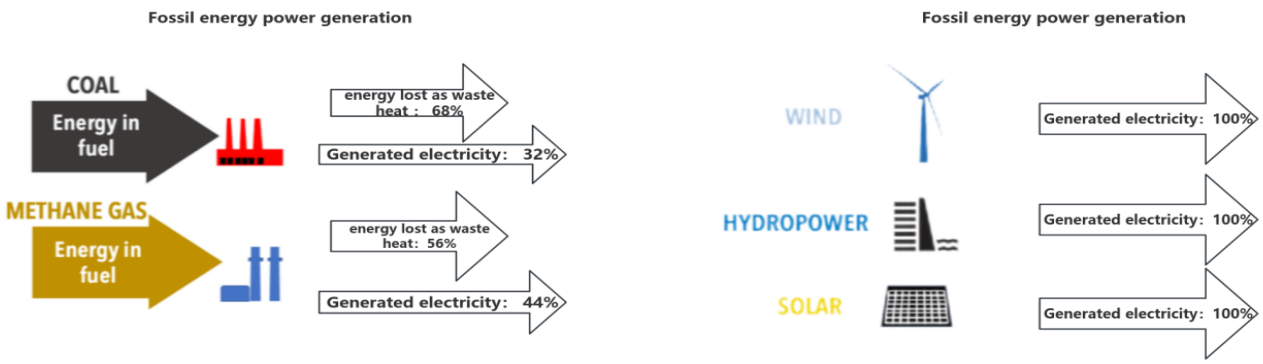


**Fig. 2** Comparison of power generation efficiency between sustainable energy and fossil energy [6]

# 3. The Impact of Transportation Electrification On the Power Grid System

## 3.1. Improve Grid Performance

Electrification of transport can optimize the use and storage of electricity from the grid. EVs can serve as an imperative local energy storage component for the grid [7]. Electric cars have the option of charging at night to use up excess power at night. In this way, the urban electricity consumption curve has become flatter [7]. That means transportation electrification can reduce power supply fluctuation and balance power supply demand. The electrification of transport will increase the demand for electricity, which will drive improvements to the grid. Electrification of transport can promote the development of battery technology and this will improve the energy storage facilities of the grid [8]. With more efficient batteries, the grid energy storage system will be improved. Electrification of transport expands the demand for the power grid, promotes the development of the power grid, and obtains economic benefits.

## 3.2. Upgrade the Power Grid

Electrification of transportation drives the transformation of the grid into the smart grid. Transportation electrification can promote grid optimization and shift to distributed generation. EVs can participate in the operation of the grid as distributed nodes of the smart grid [7]. The smart grid uses digital and other technologies to reduce the loss of electricity and improve efficiency. By effectively predicting the load, the smart grid can adjust the fluctuation of electricity consumption and reduce the pressure of the grid [9]. The smart grid can efficiently integrate renewable resources and compensate for the limitations of volatile renewable energy generation. Renewable resources have the characteristics of distribution and dispersion, which fits the situation of distributed power generation in a smart grid [9]. Smart grids utilize renewable resources, EVs and other forms to achieve improved energy efficiency. Electrified transportation promotes the adjustment and improvement of the smart grid.

# 4. Key Feature Challenge

## 4.1. Pollution

Electrified transport creates pollution in terms of production and recycling. When producing electric cars, there can be much pollution, such as water eutrophication, Excessive metal content in water [4]. Moreover, there is currently a lack of effective battery recycling solutions. A large number of waste batteries are incinerated or landfilled, which has a huge impact on the environment.

## 4.2. Cost

Electric cars are greener than gas-powered vehicles, but their initial costs are higher. Because the scale of use of electric vehicles is far less than that of fuel cars, coupled with the adoption of a large number of new technologies, its initial purchase cost is relatively high. At the current stage, the charging infrastructure is not widespread enough, and people are concerned about the endurance of EVs. These cost considerations have led to the acquisition rate of EVs is not ideal [8].

## 4.3. Pressure on Infrastructure

The electrification of transport creates a greater demand for electricity, placing greater pressure on the current grid system [8]. In some European countries, for example, transmission and distribution networks are approaching or exceeding their rated capacity [7]. If governments blindly expand the demand for electricity in transportation, other demand for electricity will be crowded out.

## 5. Suggestion and Solution

In order to solve the current problems facing electric mobility, the relevant industry should take more actions, such as researching more efficient battery systems, reducing the production cost of electric vehicles, and exploring ways to recycle batteries. At present, an idea is put forward, the secondary utilization of EV batteries. When the batteries of EVs are collected after reaching their useful life, they will gain a second life after 15 years [8]. The battery of the second life is used in the energy storage station of the power grid peak regulation. In this process, a 10 kWh lithium battery can obtain a profit of about 35% [8]. This can not only effectively reuse waste batteries but also allow manufacturers to reduce costs, which in turn will reduce prices and promote the popularity of EVs. At the same time, the participation of the government is also very important. The government could introduce relevant policies, such as tax rebates or subsidies, to encourage the development and purchase of EVs. Furthermore, They can also carry out infrastructure, such as improving the power grid and adding charging facilities. They can also standardize the production and recycling system of the industry so that the industrial chain is more standardized, efficient and environmentally friendly.

As for individuals, consumers need to take the long view. With the increase in operating mileage, the cost advantage of EVs is more obvious than that of fuel vehicles [8]. The EV structure is relatively simple, easy to maintain and cheaper. From the perspective of social trends, the trend of transportation electrification is constantly advancing. The sooner people adapt, the sooner they can enjoy its dividends. In terms of social benefits, electric mobility will accelerate the development of sustainable energy and make transportation greener.

## 6. Conclusion

This paper finds that transportation electrification has a positive impact on the environment in many ways, such as promoting the popularization of EVs to reduce exhaust emissions, improving energy efficiency to reduce resource waste, and promoting the popularization of sustainable energy. The electrification of transport will increase the demand for electricity and expand the scale of EVs. Both will accelerate the transition to smart grids while increasing the use of sustainable energy sources. Finally, society realizes environmental protection and sustainable development. Moreover, this study also found that there are some problems in the initial electrical transportation, including the high cost, the lack of uniform production and recovery standards and putting pressure on the current power grid system. Most of these problems are caused by inadequate early development of transportation electrification.

The study also provides some suggestions and solutions to the problems mentioned above, such as government guidance and encouragement and related industries to reduce costs and improve technology. This paper emphasizes the social effect of traffic electrification - environmental protection. So, there are also some limitations in this paper, such as the lack of in-depth research on the economic benefits of transportation electrification and the lack of research on specific environmental pollutants.

Future research should further explore the specific environmental impacts of transport electrification and assess the potential of smart grids and sustainable energy sources. Relevant industries should strengthen exchanges and contacts, establish unified production standards, and promote scientific and technological progress. With rising energy demand and the spread of sustainable energy, electrified transport will have a positive impact on environmental protection.

In conclusion, although there are some initial problems with transport electrification, it also provides opportunities for world development and guarantees environmental protection. With new technologies, strong policies and scientific research, transportation electrification is expected to achieve greener and more sustainable growth in the future.

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