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# Necessity and limitations of transportation electrification

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**Abstract.** In recent times, there has been a significant surge in the prioritization of electrifying the transportation sector. The heightened focus on these factors might perhaps be attributed to the industry's ability to effectively tackle and mitigate environmental problems and handle energy security challenges. This research examines the fundamental variables that are propelling the shift towards electrification within the transportation industry, alongside the limitations and obstacles linked to the extensive implementation of this technological advancement. As the transportation electrification business continues to expand, several doubts, such as spontaneous combustion, have led many to question the appropriateness of its further development. Gaining a thorough comprehension of the electrification trend and its possible constraints via an analysis of technological, economic, and infrastructural aspects proves to be very advantageous. In addition, understanding the fundamental reasons for the limitations of transportation electrification can help develop new technologies to enhance its electrification level in the future.

**Keywords:** electric vehicles, transport, greenhouse gases.

## 1. Introduction

The mitigation of greenhouse gas emissions is of utmost importance in mitigating the exacerbating impacts of global warming. According to a study of sources of greenhouse gas (GHG) emissions by United States Environmental Protection Agency in 2023, the transportation industry is responsible for about 28% of total GHG emissions [1]. The aforementioned domain is a prominent sector in which emissions persistently escalate, with passenger travel being the leading contributor, accounting for 75% of total transportation emissions [2, 3]. As a consequence, the replacement of internal combustion engines with electric powertrains can lead to a substantial reduction in greenhouse gases, including carbon dioxide, as well as other harmful pollutants, contributing to the improvement of environmental conditions. In contrast, the electrification of transportation offers a straightforward approach to mitigating greenhouse gas emissions and enhancing air quality. The use of solar, wind, and hydroelectric electricity for charging electric vehicles (EVs) facilitates the harmonization of the transportation sector with our objectives of attaining carbon neutrality and diminishing dependence on fossil fuels. Hence, the use of electric mobility has been acknowledged as a viable approach in mitigating carbon emissions.

EVs possess an inherent advantage in terms of energy efficiency when compared to their counterparts equipped with internal combustion engines. This advantage has special significance in areas where there is an abundance of fossil resources. The efficiency results in less energy usage and a transport system that is more environmentally friendly. The progression of EVs will simultaneously foster the expansion of the battery sector, which will in turn be driven by the industry's development to better its efficiency.

Amid the promising future of electrification, there are, however, the limitations and difficulties that need for serious thought and strategic preparation. For instance, EVs adoption needs a strong charging infrastructure that can keep up with the rising demand for power. Range anxiety needs to be overcome. The worry of running out of battery on lengthy excursions, particularly in high latitudes and extreme climates, remains a psychological obstacle. Additionally, there were always car incident of spontaneous combustion reported online, although this was only a selective report by the media to mislead people into thinking that EVs had a higher probability of spontaneous combustion and explosion, which led to many people still doubting the safety of EVs. This research digs into the convincing reasons behind the electrification of transport and investigates the limitations it faces. Transport electrification will play a crucial part in the realisation of a greener, cleaner, and more sustainable society in the future, and appreciating both its promise and challenges will help chart a brighter route there.

## 2. Why is electrification of transport

EVs are often regarded as an environmentally friendly option owing to their absence of exhaust emissions and their capacity to use renewable energy sources. EVs can be classified into three distinct groups based on their energy usage: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel-cell electric vehicles (FCEVs). However, for the purpose of this article, the word EVs only pertains to BEVs. Electricity, which serves as the energy source for EVs, may be generated from a diverse array of sources. Regrettably, there is currently a dearth of comprehensive data pertaining to the global energy composition utilization of EVs. The limited availability of sources of energy composition for EVs systems may be explained by the complex relationship between the power generation infrastructure of different nations and the specific energy sources used. As shown in Figure 1, in France, for instance, nuclear energy is often used for power generation, but until 2021, China's electricity will still be mainly supplied by thermal power [4, 5].

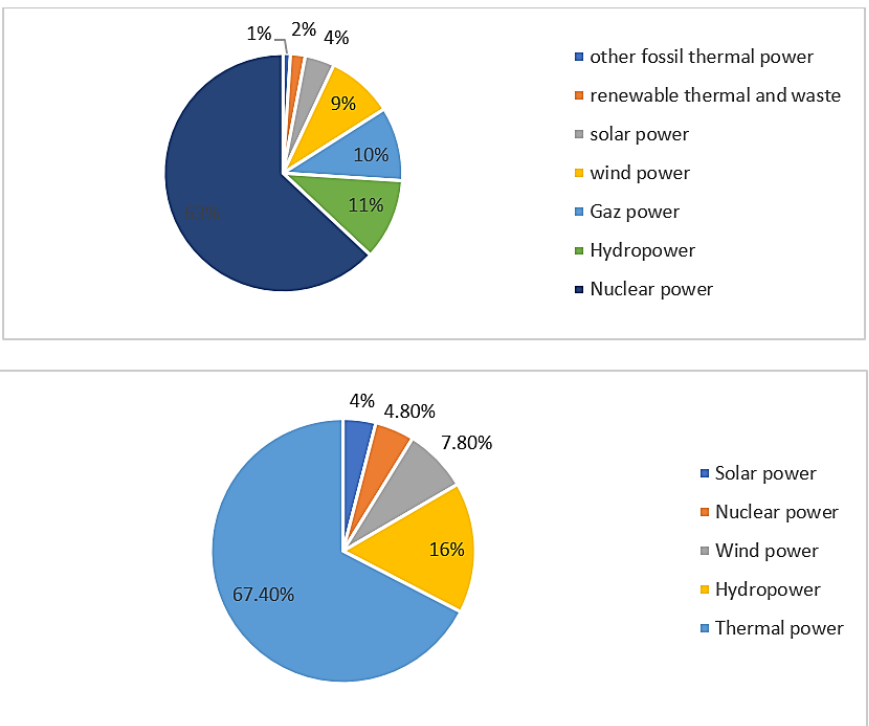


**Figure 1.** Distribution of power output in France for the year 2022 (first) and in China for the year 2021 (second) [4, 5].

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The energy composition of electricity used for EVs has pronounced regional characteristics and exhibits considerable variability contingent upon the sources of power production. These sources include a range of dominant energy types, such as renewable energy, nuclear energy, conventional fuels, and a combination of energy sources. The use of renewable energy sources will inherently lead to a reduction in their carbon footprint. However, in geographical locations where coal is the primary source of power production, the carbon emissions linked to EVs may be comparatively elevated when contrasted with places that rely on cleaner energy sources. Nevertheless, it is crucial to acknowledge that even in areas heavily reliant on coal for electricity generation, EVs may nevertheless exhibit fewer emissions compared to ICEVs owing to the superior efficiency of electric motors [6].

These possible means of energy generation mitigate susceptibility to supply interruptions within the fossil fuel industry, which might be impacted by geopolitical conflicts or natural calamities [3]. The incorporation of a varied assortment of energy sources contributes to the bolstering of energy security via the provision of different avenues for power generation. In addition, the transportation sector's notable reliance on petroleum exposes it to price fluctuations and geopolitical tensions, both of which might potentially be mitigated by the implementation of electrification strategies.

Internal Combustion Engine Vehicles (ICEVs) exhibit an estimated efficiency of 40% in terms of internal combustion, whereas EVs equipped with induction motors show efficiency levels ranging above 90%. While electric motors are widely acknowledged for their superior efficiency compared to internal combustion engines, it is crucial to consider the overall efficiency, particularly the well-to-wheel (WTW) efficiency, in order to accurately determine which kind is more energy-efficient [6], as shown in Table 1. The comprehensive WTW efficiency of gasoline ICEVs spans from 11% to 27%, while that of diesel ICEVs extends from 25% to 37%. Compressed natural gas vehicles (CNGVs) exhibit a WTW efficiency ranging from 12% to 22%. EVs that get their electrical energy from natural gas power plants have the highest well-to-wheel (WTW) efficiency, which falls within the range of 13% to 31%. The energy conversion efficiency of electric vehicles fuelled by coal and diesel power plants has comparable values, falling within the range of 13% to 27% and 12% to 25%, respectively. The use of renewable energy sources has the potential to result in a significant decrease in losses. The overall efficiency of EVs is influenced by the particular renewable energy infrastructure and its geographical location, resulting in a variability in efficiency levels ranging from around 40% to 70%. Therefore, when examining the relative efficiency of electric cars and conventional fuel vehicles, it is often said that the WTW efficiency of induction motors or EVs fuelled by renewable energy sources is greater.

**Table 1.** Efficiency of different vehicles [6].

| Vehicle types | Efficiency | Vehicle types | Efficiency |
|---|---|---|---|
| Gasoline ICEVs | 11% to 27%, | Coal EVs | 13% to 27% |
| Diesel ICEVs | 25% and 37% | Diesel EVs | 12 % to 25% |
| CNGVs | 12% to 22% | Renewable energy EVs | 40% to 70% |

The operating costs of EVs are significantly lower than those of ICEVs. More specifically, the operating costs associated with vehicles use can be broken down into two primary categories: energy costs and maintenance expenses. First, it is essential to recognize that there is a significant difference in the cost of energy used by these two categories of vehicles. Fluctuations in the market price of crude has a substantial impact on the price of petroleum for conventional vehicles [7]. Prior to the beginning of pandemic of COVID-19, the price of a litre of petrol in Ontario, Canada was approximately1.40 Canadian dollars (0.82 pounds). However, following the outbreak of conflict, the price of petrol remained above 2 Canadian dollars (1.17 pounds) for an extended period [8]. In contrast, electric vehicle systems (EVS) are less susceptible to fluctuations in electricity costs. EVs are, on average, more energy-efficient than their gasoline-powered counterparts. Consequently, EVs have substantially lower energy consumption than ICEVs. EVs require less maintenance due to their basic design, resulting in lower maintenance and service costs. EVs often exhibit a greater initial expense compared to conventional

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ICEVs, partly attributable to the significant expenditures involved with battery manufacturing. EVs continue to rely on relatively novel technology and have not achieved comparable cost reductions to gasoline-powered vehicles. In addition, the industrial supply chain sustaining EVs is not as refined as that of gas-powered vehicles, which contributes to their relatively higher initial cost. Consequently, recent advances in battery technology have played a crucial role in making electrification possible. The decreased costs and increased energy density of lithium-ion batteries have significantly contributed to the increased availability and viability of EVs for consumers.

Despite the notable advancements achieved in battery technology, concerns over the restricted driving range, often known as range anxiety, persist as a prevalent concern among potential consumers of EVs. Another subtle issue related to the range of EVs is the disparity between the displayed range on the vehicle's dashboard and its real range. The issue under consideration is not limited just to EVs, but ICEVs also encounter this obstacle. Nevertheless, due to the higher quantity of gas stations that are accessible, this issue is less prominent for ICEVs. On the other hand, EVs tend to have an amplified version of the challenge by range anxiety. Although there is a need for advancements in EVs, it is equally important to provide a robust and widespread charging infrastructure to effectively tackle this challenge. There is a need to focus on the establishment of efficient charging networks and the enhancement of charging station availability in urban and rural areas.

The use of rare earth elements and minerals is essential in the manufacturing process of lithium-ion batteries. The proliferation of battery manufacturing in response to the increasing need for EVs has the potential to result in limitations on resources and environmental challenges linked to the extraction and refining processes of these materials. As the use of EVs in transportation networks becomes more widespread, there will be a corresponding rise in the demand for energy. One of the possible consequences associated with this occurrence is the possibility of overburdening existing power networks, particularly during times characterized by a high demand for charging. The significance of refurbishing and enlarging the grid to accommodate heightened energy requirements cannot be overstated, as it is crucial for averting power disruptions and guaranteeing a consistent supply of electricity. EVs exhibit worse performance under extreme temperature conditions as compared to more moderate ones. This imposes limitations on the sales of EVs in areas characterized by either high latitudes or tropical conditions. Let us take low temperatures into consideration as an illustrative case. The use of a positive temperature coefficient (PTC) heater in an environment with an ambient temperature of -10 °C may lead to a notable decline in the driving range, with a potential degradation rate of 31.7% [9]. Consequently, this might result in substantial energy inefficiencies.

Additionally, there are more nuanced reasons that impose constraints on EVs, including the prevalent media coverage of spontaneous combustion incidents associated with EVs. This coverage engenders scepticism among several customers about the safety of EVs. However, based on report using the data from the National Transportation Safety Board (NTSB) on divided by the sales data from Bureau of Transportation Statistics (BTS), it can be seen that EVs exhibit the lowest incidence of spontaneous combustion, so establishing their superior safety performance in this aspect (IVEV: 3474.5 fires vs. EV: 25.1 fires per sale) [10]. The argument posits that instances of EVs fires get significant media attention, but incidents involving conventional vehicles do not receive comparable coverage.

Ongoing investigation into battery technology, materials science, thermal insulation, and energy storage technologies is needed in order to surmount the constraints associated with electrification. It is recommended that governments maintain and enhance supporting policies in order to mitigate the substantial initial expenses and foster the widespread adoption of EVs. Various incentives, including tax credits, rebates, and preferred treatment for EVs in public locations, have the potential to enhance the appeal of EVs among customers. The implementation of charging infrastructure is crucial in mitigating concerns over limited driving range and encouraging the widespread use of EVs. It is essential for the public and commercial sectors to engage in collaborative efforts aimed at establishing an extensive network of charging stations, including both fast chargers situated along roads and inside metropolitan areas. Promoting consumer awareness on the advantages of electrification and dispelling any misunderstandings might facilitate enhanced levels of acceptability. Public awareness campaigns play a crucial role in disseminating precise information pertaining to EVs performance, charging alternatives, and environmental benefits. This stands in stark contrast to the potential pitfalls of relying on social media propaganda, which may propagate unfounded claims such as the notion that EVs are prone to spontaneous combustion.

## 3. Conclusion

This research examines the potential benefits of electrifying the transport industry, including the reduction of emissions, enhancement of energy security, cost savings for customers, and promotion of technological advancements. The process of electrifying transportation represents a substantial shift in the way mobility and energy use are understood. Nevertheless, it is crucial to recognize and address certain constraints and obstacles in order to achieve a successful transformation. The successful implementation of broad electrification in the transportation sector may be aided by the efficient resolution of several difficulties pertaining to range anxiety, still not enough infrastructure, temperature influence on range of EVs and safety concerns consumer may remain.

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