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Performance Comparison of BEV and PHEV under Beijing Policy Incentives (2020-2025)

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Abstract:

The study aims to discuss the performance comparison between battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) in the context of policy incentives in Beijing from 2020 to 2025. Under the impetus of sustainable development policies, Beijing has guided the popularization of new energy vehicles through a series of policies to reduce operational energy consumption and carbon emissions. The study will compare and analyze their overall performance from background, technical principles, energy consumption, and full life cycle carbon emissions. BEVs have significant advantages in energy consumption and full life cycle carbon emissions, but they face challenges such as low energy density batteries and uneven distribution of charging facilities; PHEVs rely on fuel resources and cause higher carbon emissions. The study expects that both will coexist in the short term, but with the strengthening of low-carbon requirements and the improvement of infrastructure, BEVs are expected to gradually take the lead.

Keywords: Battery Electric Vehicle (BEV); Plug-in Hybrid Electric Vehicle (PHEV); policy incentives; operational energy efficiency; life-cycle carbon emissions.

1. Introduction

By integrating comprehensive references and policies, the study analyzes the performance characteristics of pure electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) under the policy incentives in Beijing from 2020 to 2025, with a focus on energy consumption and life cycle carbon emissions. The entire research is based on comparative analysis, and ultimately summarizes the advantages and limitations of the two vehicle types under policy-driven conditions. This aims to provide a reference for understanding the low-carbon development path of future urban transportation.

Under global energy transition and environmental protection, battery electric vehicles (BEV) have received promotion from various countries as they represent zero exhaust emissions. Beijing, as a pioneering city in promoting new energy vehicles in China, has introduced a series of policies to support the development of BEVs since 2010, including special license plates for new energy vehicles, purchase subsidies [1]. During the period from 2020 to 2025, Beijing's support policies for BEVs have been continuously optimized, such as increasing subsidies for models with high range and high energy density, and accelerating the layout of charging infrastructure. These policies have driven the rapid penetration rate of BEVs in Beijing's market, like increased by 1.9 times in 2022 [2], with BEVs taking the leading position.

Plug-in hybrid electric vehicles (PHEVs) are an important type of vehicle for the transition from traditional fuel vehicles to pure electric vehicles, possessing both pure electric driving capabilities and fuel backup power. Beijing's policy support for PHEVs began in 2016, when they were included in the management category of new energy vehicles [3]. During the period from 2020 to 2025, Beijing's policies for PHEVs were further clarified, such as requiring that the pure electric range of PHEVs be no less than 50 kilometers (the 2020 standard) and gradually increasing it to 80 kilometers (the 2025 plan) [4], in order to encourage automakers to enhance their pure electric driving capabilities. As BEV technology becomes more mature and charging facilities are improved, the positioning of PHEVs may further shift towards "long-range transition vehicles", but in the short term, they remain an important supplement under policy support.

2. Methods

This study employed a systematic comparative analysis method, integrating quantitative data assessment with policy analysis, to evaluate the performance of pure electric vehicles (BEV) and plug-in hybrid electric vehicles (PHEV) under the constantly changing policy incentives in Beijing. The data and policy documents were sourced from authoritative academic databases and official government websites (Beijing Municipal Commission of Economy and Information Technology, Beijing Municipal Commission of Transport, Beijing Municipal Bureau of Statistics, etc.), including policy notices, implementation plans, statistical bulletins, and model directories issued by relevant departments.

From a quantitative perspective, the study compared key indicators: operational efficiency, energy consumption, and lifecycle emissions, and supplemented with standardized calculation formulas. From a qualitative perspective, it examined the unique policy texts in Beijing, focusing on the stipulated mechanisms (subsidies, minimum range requirements, infrastructure support) and their impacts.

Through a comprehensive analysis of quantitative and qualitative evidence, the study summarized the advantages and limitations of each vehicle type.

3. Results & Discussion

3.1 Overview of Working Principle

3.1.1 Battery electric vehicle

The core working principle of a battery electric vehicle (BEV) is to store electrical energy in the on-board battery, and then the motor directly converts the electrical energy into mechanical energy to drive the vehicle without going through the thermal engine stage. Therefore, theoretically, it has a higher energy conversion efficiency. The power system of a BEV mainly consists of the battery, the drive motor, and the motor controller.

3.1.2 Plug-in hybrid electric vehicles

Plug-in hybrid electric vehicles (PHEVs) combine the dual characteristics of pure electric drive and fuel-driven operation. Their power system includes battery power, electric motors, internal combustion engines, gearboxes, etc. In the pure electric mode, PHEVs rely solely on electric motors for propulsion, and the energy conversion path is the same as that of battery electric vehicles (BEVs); in the hybrid mode, the internal combustion engine and the electric motor can work together.

3.2 Energy Consumption

3.2.1 Data Comparison

The energy consumption of Battery Electric Vehicles (BEVs) is typically expressed in terms of electricity consumption per 100 kilometers (kWh/100km). BEVs feature relatively high energy conversion efficiency. In 2023, he mainstreams BEV models in Beijing, the electricity consumption ranged from 12 to 18 kWh/100 km [5]. This level is attributable to the improvement in motor and the policy incentives for high - energy - density batteries. High-energy-density batteries can reduce the curb weight of vehicles, thereby decreasing electricity consumption.

Regarding Plug - in Hybrid Electric Vehicles (PHEVs), their energy consumption needs to be differentiated between the pure - electric mode and the hybrid mode. In the pure - electric mode, the electricity consumption per 100 kilometers of PHEVs is similar to that of BEVs in the same class, approximately 15 - 20 kWh [5]. In the hybrid mode (when the battery power is insufficient), the energy consumption of PHEVs is measured by the fuels use(L/100km). Policy requirements for the pure - electric range of PHEVs, such as reaching 80 kilometers by 2025, have motivated automakers to optimize the electricity in the pure-electric mode, thereby reducing fuel consumption

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in actual use [6].

3.2.2 Equations Comparison

As for BEV, Cpc, the energy consumption of BEV, can be quantified by the power consumption rate, and the core equation is:

$$C_{pc} = C_{output} / S * 100 \quad (1)$$

In this equation, Coutput represents the power output from the power supply (which is the electrical energy output by the battery, measured in kWh), and S represents the driving distance (km).

Considering PHEV, Fcom, the energy consumption of PHEV in hybrid mode is commonly represented by "weighted fuel consumption". The calculation requires taking into account both the pure electric mileage or the fuel mileage, and the equation is:

$$F_{com} = F_{fuel} * D_{fuel} + 100 * (E_{consume} * C_f) / D_{total} \quad (2)$$

In this equation, Ffuel represents the fuel/electric consumption per 100 kilometers(L/100km), Dtotal represents the total mileage(km) traveled, Dfuel/Deletric is the distance(km) traveled when the engine is operating, and Econsume is Total electricity consumption (kWh). Cf is electric-to-fuel conversion coefficient (L/kWh). (For example, according to the Chinese standard GB/T 37340-2019, Cf = 0.31 L/kWh)

3.3 Full life cycle carbon emissions

In 2019, Beijing, the carbon emissions of BEVs are generally lower than those of PHEVs. The total life-cycle emissions of BEV (LFP battery) are 128.80 g CO_2-eq per km, while those of PHEV (LFP battery) are 190.58 g CO_2-eq per km. The emissions of PHEV are approximately 48% higher than that of BEV [7]. Also, the BEV reduces greenhouse gas emissions by 15.95% (for NMC batteries) to 26.32% (for LFP batteries) compared to the PHEV [7].

It indicates that Beijing's power supply is mainly based on coal-fired power, which results in: the "fuel cycle" (Well-to-Pump, WTP) emissions of BEV accounting for a high proportion [8]. At the same time [8], mentions that the annual mileage of users in Beijing is relatively low (approximately 10,000 kilometers per year for BEV potential users), which weakens the emission reduction advantage of BEVs during their usage stage. In the short term, PHEVs' fuel flexibility may better suit low-mileage Beijing users.

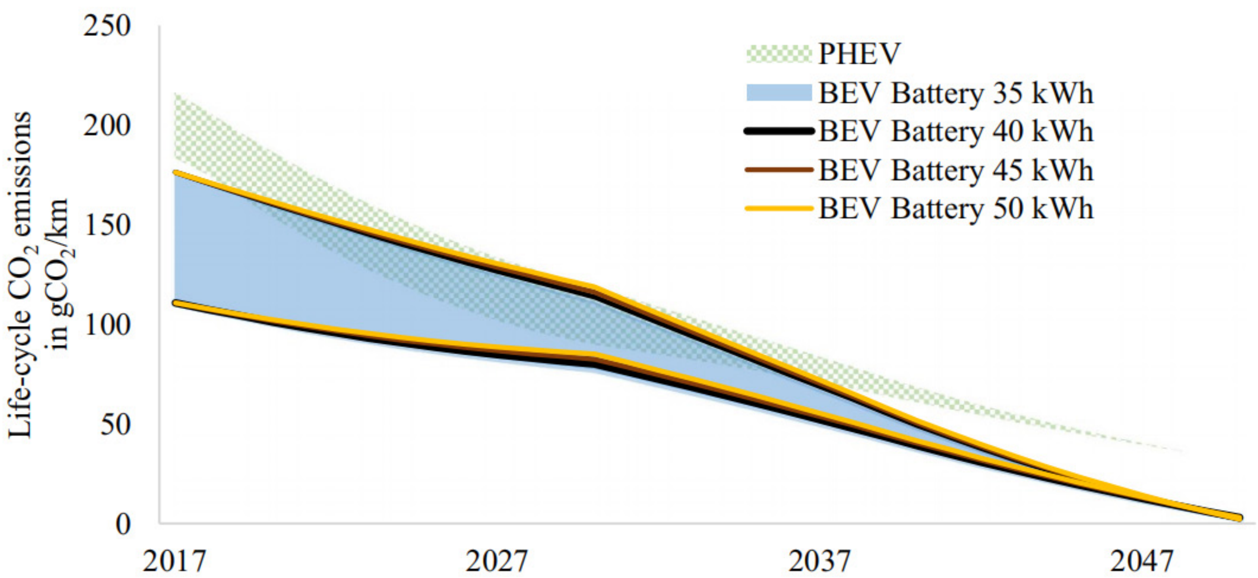

Fig 1. Life-cycle CO_2 emissions in gCO_2/km for newly sold PHEVs over time and for different battery capacities' BEVs [9].

However, in life-cycle, figure 1 illustrates the overall projected CO_2 emissions reduction trajectories for BEVs and PHEVs globally (including China) from 2017 to 2047. It clearly shows a significantly steeper decline for BEVs in the long term. Although the relatively low annual mileage of users in Beijing and grid situation may temporarily weaken the emission reduction advantage of BEVs during use [8], as shown in Figure 1, the long-term trend of dramatic decline in global (including China) BEV life cycle CO_2 emissions [9], will effectively counteract this effect and demonstrate greater emission reduction potential throughout the vehicle's entire life cycle.

Therefore, though Beijing's current grid and mileage weaken BEV benefits, the long-term trend probably will amplify BEV superiority as grid decarbonizes (e.g., to support, Beijing's 2025 target: the carbon dioxide emissions per unit of GDP be reduced by more than 20% compared to 2020, which requires the acceleration of the clean-up of the power grid, indirectly promoting BEV use) [10, 11].

3.4 Social Acceptance and Policy Influence

Under the policy incentives of Beijing Municipality, the advantages of BEVs (Battery Electric Vehicles) are mainly reflected in: high energy consumption (low electricity cost), low lifecycle carbon emissions, enjoying policy benefits like the new energy license plate (no lottery required), and charging infrastructure subsidies [12, 13]. However, their disadvantages are also evident: range is significantly affected by low temperatures, public charging facilities remain insufficient during peak hours (especially in commercial districts), and the power battery recycling system is not yet perfected [14].

The advantages of PHEVs (Plug-in Hybrid Electric Vehicles) lie in: flexible range (no range anxiety), good energy stability in winter, pure electric mode can meet daily commuting needs while still enjoying policy benefits. Their disadvantages include: higher maintenance costs than BEVs due to system complexity, and life-cycle carbon emissions still higher than BEVs [8].

To sum up, from statistics, most drivers with stronger environmental awareness tend to prefer BEVs, considering them the future trend. To be specific, for instance, the Beijing Consumers' Association released that, compared with traditional fuel vehicles, 59.34% of the respondents believed that new energy vehicles are environmentally friendly and energy-saving [13].

4. Conclusion

In conclusion, under the policy incentives of Beijing from 2020 to 2025, BEV demonstrated the potential to become the mainstream of future transportation due to its higher energy consumption and lower carbon emissions throughout the life cycle. PHEV, with the flexibility of "pure electric + hybrid", became a transitional choice to alleviate range anxiety under policy support, but its carbon emissions throughout the life cycle are still higher than those of BEV, and the potential policy subsidies' reduction has gradually weakened its cost advantage. In the short term, the two types of vehicles will coexist in the Beijing market. However, in the long term, driven by policy incentives and technological progress, BEV will lead the low-carbon transformation of urban transportation, while PHEV may continue to play a supplementary role in specific scenarios (such as for users with high demand for long-distance travel).

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