Does the Popularization of New Energy Vehicle Facilitates the Improvement of Air Quality? Taking China as Evidence

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Abstract. Automobile exhaust always makes up a significant portion of the causes of air pollution, and new energy vehicles (NEV) are being investigated as a potential solution to the problem of urban air pollution. Through a number of policy incentives and infrastructure improvements, the Chinese government encourages the quick development of the new energy automotive sector. National air quality has also improved dramatically in recent years. In this context, the primary goal of this study is to explore whether there is a significant positive correlation between the popularization of NEVs and air quality. This study looks for data on the penetration rate of NEVs in various provinces and cities across the country, as well as the data on the number of days with air quality, and makes a visual chart to show the change trend from 2013 to 2022. Finally, policy recommendations are given. The government should adapt to local conditions and continue to boost the infrastructure of NEVs. In addition, clean energy power generation, sustainable production and recycling should be actively promoted from the perspective of the whole life cycle of NEVs.

1 Introduction

Pure electric and hybrid vehicles are examples of new energy vehicles (NEV), which are propelled by renewable energy or non-fossil fuels and can significantly lower air pollution emissions while also improving urban air quality. With the adjustment of the global energy structure and the aggravation of climate change issue, countries have proposed plans to achieve carbon neutrality. China wants to achieve carbon neutrality by 2060 and reach its peak in carbon dioxide emissions by 2030. As an important part of the transportation sector, vehicle emissions are one of the primary sources of carbon emissions. Therefore, the popularization of NEVs can reduce the use of fuel vehicles and reduce carbon emissions, which is conducive to the realization of carbon neutrality and the improvement of air quality.

In the international new energy vehicle industry, developed countries such as Europe and the United States are relatively advanced in NEV technology, especially in the field of electric vehicles. China's domestic new energy vehicle technology is also constantly innovating, with an increasing variety of vehicle models, gradually improving driving range, and decreasing costs. In recent years, the Chinese government has continuously implemented a series of policies to encourage the development of NEVs, such as purchase subsidies, exemption from purchase tax, and free parking. Coupled with the continuously increasing awareness of energy conservation and environmental safeguarding among consumers, the market size of NEVs is expanding continuously.

In the meanwhile, the popularization of new energy vehicles can also promote the overall development of the new energy industry, improve the energy structure and promote the transformation and upgrade of the economic development model. The manufacture of NEVs necessitates the use of numerous components such as batteries and motors. The development of these industries will also drive the development of related industry chains, forming new growth points for the economy.

However, the question remains whether the popularization of NEVs and related favorable policies will truly contribute to improving air quality. While NEVs themselves produce few air pollutants, the production and disposal of batteries and other components may have negative environmental impacts. Additionally, the energy sources used to power NEVs may still be dependent on fossil fuels in some regions, limiting certain benefits for the environment. Therefore, it is essential to assess the full effects of NEVs on the ecosystem and air quality.

This paper will use the cost-benefit model to analyze the popularity of NEVs in different regions of China, and explore the reasons for the differences and the impact on the improvement of air quality. Taking into account the new energy automobile industry's entire life cycle's impact on the environment, the corresponding policy recommendations are put forward.

2 Literature review

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Numerous studies indicate that the use of conventional fuel vehicles has a negative impact on air quality and that long-term exposure to traffic pollution can pose health risks to human. Zhang et al. (2020) collected urban atmospheric fine particulate matter in the Beijing-Tianjin-Hebei region and analyzed the sources of its carbon components, finding that vehicle exhaust from conventional fuel vehicles is one of the main sources of urban PM2.5 [1]. Wang et al. (2023) verified that urban traffic contamination has a serious impact on residents' health through the time distribution method of motor vehicle emissions and the CMAQ model [2]. Despite the fact that PM2.5 levels have significantly decreased in China, it still attracts a lot of attention because of the strong link between adverse health condition and climate crisis [3].

The promotion of NEVs has positive implications for improving air quality. Zhang et al. (2020) studied the impact of subsidy policies for NEVs about the decrease of air pollution emissions and conducted scenario analysis, drawing a conclusion that electric taxis and special vehicles have significant potential for curbing greenhouse gas emissions and hazy weather, respectively [4]. Adila et al. (2020) investigated the collaborative emission-lowering effect and cost of electric automobiles in Shanghai and discovered that widespread adoption of new energy vehicles would have a beneficial impact on the diminution of PM2.5, NMHC, PM10, CO, NOx, and CO_2 emissions [5].

Zhao et al. (2022) studied the spatial-temporal evolution characteristics and socio-economic driving forces of China's air quality during 2016-2020, and concluded that China's air quality improved significantly. Among them, social development is the main reason for the difference between the eastern economic belt and the central and western economic belts [6]. Wu et al. (2022) found that the provincial (municipal) new energy vehicle competitiveness has obvious spatial and regional differences, showing a pattern of "strong in the east, weak in the middle and the west, and local jumping" [7].

The impact of electric vehicles in China on reducing emissions, however, has been hotly debated. Yang et al. (2021) employed the life cycle evaluation (LCA) approach to evaluate carbon dioxide and atmospheric pollutant emissions from the stage of vehicle manufacture, vehicle use, and vehicle end-of-life while taking into account the emission of new energy vehicles over their whole life cycle [8]. The study discovered that, if the electric emission factor remained constant, the PM 2.5 and SO_2 emissions in a high renewable energy scenario with a larger share of biomass were higher than those of an internal combustion engine vehicle (ICEV).

In terms of existing studies, the relationship between motor vehicles and air quality has made some progress, but there are still some controversies and limitations. For example, the pollution cost of the whole process of new energy vehicles including design, production, use, and scrap recycling, etc. Therefore, it is necessary to study the interaction between various factors in order to better formulate effective policy measures to reduce urban traffic pollution.

3 Current situation of air quality and NEV market in China

3.1 Main air pollutants and sources

The main pollutants emitted by motor vehicle exhaust are nitrogen oxides, solid particle matter, lead compounds, hydrocarbons, nitres, sulfur dioxide, and carbon monoxide. Therefore, according to China Environmental Statistical Yearbook, taking nitrogen oxides as an example, the data of national nitrogen oxides emissions from 2011 to 2020 can be selected to analyze the main sources of pollution and the changing trends.

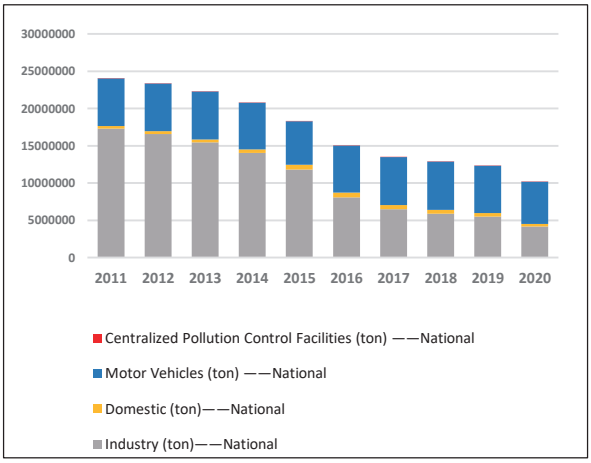

Fig. 1. Nitrogen oxide emission distribution in China (Photo credit: Original).

Figure 1 shows four modes of nitrogen oxide emissions, including industrial, domestic, motor vehicles and centralized pollution control facilities. The industrial emissions have declined significantly over the past decade, reaching 4,174,959 tons by 2020. Exhaust emissions from motor vehicles have been declining in recent years, but the share has continued to rise and reached 55.6% in 2020 (as shown in Figure 2). Mobile sources have replaced industrial sources as the main source of nitrogen oxide pollution. Therefore, it is of great significance to develop electric vehicles and reduce mobile pollution sources to improve air quality.

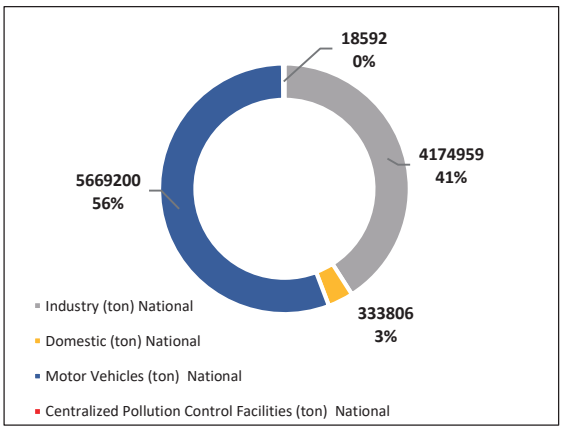

Fig. 2. Sources and proportions of China's nitrogen oxide emissions in 2020 (Photo credit: Original).

3.2 The popularization period of NEVs

3.2.1 The penetration rate of NEVs

The penetration rate of new energy vehicles refers to the proportion of NEV sales to total automobile sales during a certain period. The penetration rate is not only related to the achievement of carbon peak and carbon neutrality goals, but also has guiding significance for the government's formulation of new energy industry support policies, charging infrastructure construction plans, and so on.

$$\text{Penetration rate} = \frac{\text{new energy market}}{\text{overall market}} \times 100\% \quad (1)$$

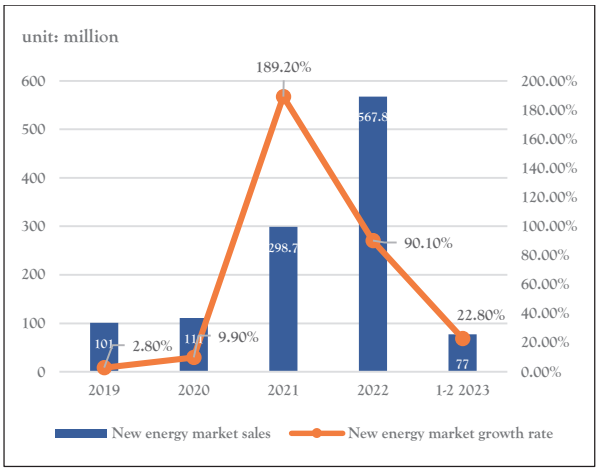

Fig. 3. Annual sales volume and growth rate of NEVs in China (Photo credit: Original).

With the continuous development and improvement of NEV industry, the popularity of NEV market has undergone a qualitative change. It can be seen from Figure 3 that the sales of NEVs have been increasing in recent years, and the market is broad. The 2021-2035 Development Plan for the New Energy Vehicle Industry in China, released in 2020, clearly stated the goal that the penetration rate of NEVs will reach 25% by 2025. In fact, according to Figure 4, the penetration rate of NEVs in China reached 27.6% in 2022, an increase of 12.6 percentage points compared to 2021, achieving the goal three years ahead of schedule.

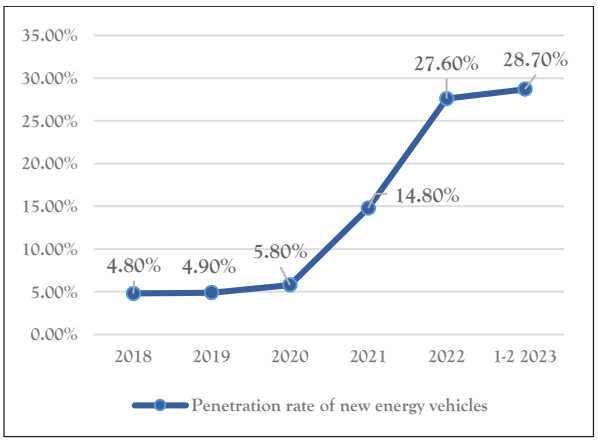

Fig. 4. Annual penetration rate of NEVs in China (Photo credit: Original).

Note: Overall market (sedan, MPV, SUV): ICEV+BEV+PHEV; New energy market (sedan, MPV, SUV): BEV+PHEV; ICEV: Internal Combustion Engine vehicle; BEV: Battery Electric vehicle; PHEV: Plug-in hybrid electric vehicle.

The increasing sales of NEVs stems from a series of favorable policies introduced by the government. In 2009, Chinese government paid manufacturers 9.3 thousand USD for each electric car.Since 2011, Beijing has established required procedures to assign new vehicle quotas (which were 240,000 units in 2011) through a lottery system in order to enhance the share of electric vehicles in total vehicle volume by regulating the growth of small passenger fuel vehicles. In 2014, the categories of electric automobiles to be introduced are added to the composition of the structure of vehicle quotas. In 2015, Beijing electric car buyers have obtained an exemption from vehicle purchase tax [9]. In 2022, although the purchase tax incentives for new energy vehicles were halved, the sales volume of NEVs was not affected, and the penetration rate increased even more than expected. These fiscal, tax, parking incentives, transportation facilitation and other measures have, to some extent, increased the popularity of energy-saving and environment-friendly electric vehicles, providing a strong impetus for the development of the electric automobile industry.

3.2.2 The air quality trends during this period

Table 1 selects the capital cities of 31 provinces in China to count the number of days each year when the annual air quality reaches level II (Grade II<100) or above. Class II and above days are based on the comprehensive assessment results of the three pollutants, which are more representative of the city's overall air quality level.

Table 1. Days of air quality equal to or above grade II (days).

	2013	2014	2015	2016	2017	2018	2019	2020
Beijing	167	168	186	198	226	227	240	276
Tianjin	145	175	216	226	209	207	219	245
Shijia zhuang	49	97	180	172	151	151	174	205
Taiyuan	162	197	230	232	176	170	200	224
Huhhot	213	240	276	283	255	272	292	294
Shen yang	215	190	207	249	256	282	284	287
Chang chun	230	239	237	291	276	322	306	305
Harbin	239	241	227	282	271	310	304	303
Shang hai	246	278	252	276	275	295	309	319
Nanjing	198	188	231	242	264	251	255	304
Hang zhou	212	216	242	260	271	269	287	334
Hefei	180	151	238	253	224	260	257	311

Fu zhou	343	310	344	361	349	337	360	364
Nan chang	230	294	311	318	300	327	322	335
Jinan	79	107	124	168	181	188	182	223
Zheng zhou	134	135	136	159	166	168	177	230
Wuhan	161	177	189	237	255	249	245	309
Chang sha	196	224	257	266	262	278	275	309
Guang zhou	259	282	312	310	294	294	293	331
Nan ning	275	292	324	348	337	340	346	357
Haikou	342	346	349	361	352	356	342	361
Chong qing	207	246	292	289	277	295	309	331
Cheng du	139	216	211	214	235	251	287	280
Gui yang	278	301	340	350	347	357	358	362
Kun ming	329	350	350	362	360	361	356	366
Lhasa	341	321	313	313	361	358	364	366
Xi'an	157	172	250	192	180	187	225	250
Lan zhou	193	247	252	243	232	213	296	312
Xining	216	261	295	271	294	282	346	337
Yin chuan	249	255	259	252	232	249	324	301
Urumqi	184	202	218	246	241	255	277	279
Annual mean	211 .87	229. 61	253 .16	265 .29	261 .58	269 .71	284 .23	303 .55

Source: China Statistical Yearbook on Environment.

The table above makes it unambiguous obvious that the overall air quality in most provinces and cities in China during 2013-2020 tends to be better, reaching level II (Grade II<100) or above days have significantly increased.

3.3 Research analysis

This study concentrates on the contribution of terminal use of NEVs to air quality, and explores the relationship between the changing trend of penetration rate of NEVs and the changing trend of air pollution level.

To make the air regime shown in the following figure more realistic, the average number of days with air quality below good level in 2022 is selected and plotted by GeoDa software. As shown in Figure 5, the lighter colors in the southern region indicate that there are fewer days with air quality at pollution levels, and overall air quality is better than in the northern region.

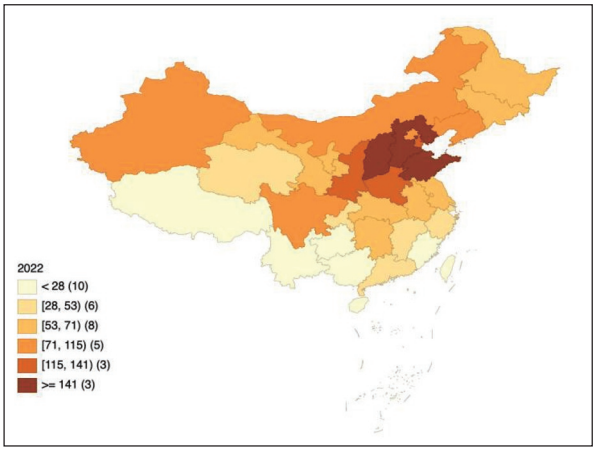

Fig. 5. Average annual number of days with air quality below Grade II in 2022 (Photo credit: Original).
Source: China Statistical Yearbook on Environment.

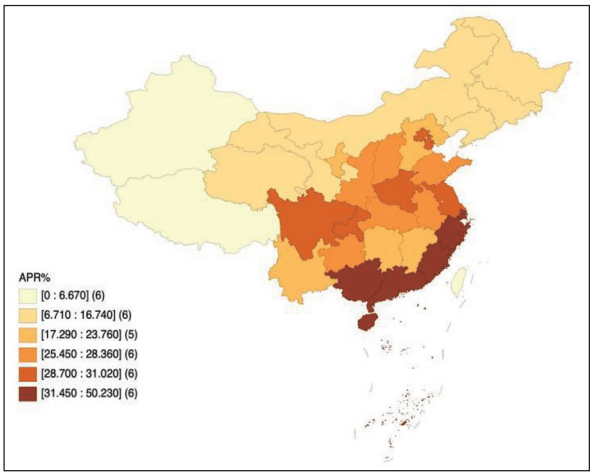

Fig. 6. Market penetration rate of NEVs in China's provinces in 2022 (Photo credit: Original).
Source: China Passenger Car Association.
Note: APR-Annual penetration rate.

Overall, the penetration rate of NEVs in South and East China is generally higher than that in North and West China (see Figure 6). Among them, influenced by such factors as mild climate, perfect infrastructure, strong promotion policies and strong consumption potential, some coastal and central provinces and cities have become the leaders in the development of NEVs. Specifically, the penetration rate of electric automobiles in Shanghai, Hainan, Guangxi, Chongqing, Zhejiang, Tianjin and Beijing all exceeds 30%, ranking in the first echelon of new-energy vehicle development.

In addition, suitable climate and geographic environment play a crucial role in promoting the adoption of NEVs. Generally, the optimal temperature for power batteries is similar to the human body's suitable temperature, and extremely cold weather can significantly reduce the driving range of electric vehicles. Under the condition of minus 15℃, the average driving range achieved by new energy vehicles is only 48.5%. This has also led to the fact that provinces with low penetration rates of new energy vehicles generally have lower winter temperatures, such as Jilin, Liaoning, Inner Mongolia, Heilongjiang, Qinghai,

Xinjiang, etc. It is reported that the average winter temperature in Xinjiang is below minus 20℃, while the winter temperature in Heilongjiang is generally below minus 15℃.

Therefore, the positive correlation between the increase in the popularity of NEVs in the southern region and the improvement of air quality is more significant. The complex geographic environment of Qinghai, Tibet, and other areas is not conducive to the deployment of charging and swapping infrastructure, which is one of the reasons for the slow promotion of NEVs.

4 Limitation and outlook

Although this paper reveals that compared with traditional cars, new energy vehicles can enhance air quality to a certain extent, there are still some limitations. First, this paper does not consider the cost-benefit balance of the whole life cycle of new energy vehicles such as design, production, use and recycling, and only analyzes its environmental protection effect in the final use link, namely the emission problem of mobile terminal [10]. Second, the penetration rate of NEVs examined in this research is the national average level, without taking regional variations into account. For example, the different climate in the north and the south leads to the great difference in the endurance capacity of new energy vehicles. Additionally, it's crucial to distinguish between local and global effects, particularly when it comes to air pollutants like SO_2 and PM2.5 [11]. Third, the data selected in this paper have certain limitations. Data accessibility is not complete because some data are not disclosed, or the years of public disclosure are incomplete.

In the further research, it is possible to explore the differences in the promotion effect of electric vehicles in different economic zones or regions, and explores the air quality changes over a longer period. These studies help determine the regions with the best promotion effect of new energy, and design local policies accordingly.

5 Conclusion

According to the above research on the nexus between the market penetration rate of electric automobiles and the air quality in China, this paper found a similar trend of change between the two, that is, the continuous increase in the penetration rate of NEVs has a certain effect on improving air quality, and there is a certain positive correlation. Based on this, this paper gives some policy suggestions to promote China's new energy cars market and improve the air quality.

5.1 Improving the infrastructure of new energy vehicle

China has a vast land area and a large population. Different provinces and cities have different policies and promotion models for new energy vehicles. Therefore, the actual policy implementation process needs to consider factors such as climate conditions, geographical environment, and city positioning, and implement flexible and differentiated policy management according to the economic development and consumption levels of different cities, as well as the acceptance of new environmental protection industries.

At the same time, establishing a better new energy vehicle infrastructure can accelerate the popularization of new energy vehicles, thereby reducing environmental pollution. The government can attract more private individuals and enterprises to invest in the construction of NEVs charging piles through subsidies, electricity fee reductions and other means. In addition, the government should also strengthen investment in the field of public transportation, such as promoting NEVs in the fields of buses and taxis.

5.2 Promoting the clean energy power generation

The improvement of air quality fundamentally depends on the adjustment of the national energy structure. Therefore, it is necessary to further optimize the energy structure, utilize all available solar energy resources, develop photovoltaic power stations, photovoltaic parking lots, etc., and promote the coordinated development of photovoltaics and electric vehicles.

When discussing the improvement of air quality by new energy vehicles, it should not only focus on the emissions of vehicles during operation, but also consider the emissions of the entire life cycle, and formulate comprehensive policies. For example, new energy vehicles need to be driven by electricity, so the promotion of clean energy power generation is the key to decrease life cycle pollutant discharge of NEVs. In addition, the administration should encourage companies to invest in clean energy power generation facilities through financial subsidies, tax incentives and guide these companies to establish recyclable treatment systems so that waste can be better reused.

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