Proceedings of ICEGEE 2026 Symposium: AI-Based Medicine and Biological Data Analysis
DOI: 10.54254/2753-8818/2026.AU34801

Vehicle Electrification and NO_2 Improvement under Sustained Policy Support: Evidence from Shanghai

Ziran Xu

School of Atmospheric Science,Nanjing University of Information Science & Technology, Nanjing, China
202383300194@nuist.edu.cn

Abstract. This study examines the relationship among new energy vehicle (NEV) promotion, vehicle structure change, and air-quality change in Shanghai from 2015 to 2024. Instead of trying to identify a strict causal effect, and changes in pollutant indicators moved in a broadly consistent way over time. NO_2 is used as the primary indicator because it is more directly related to traffic emissions, while PM2.5 is used as supporting evidence. To reduce seasonal interference, this study uses April–October mean concentrations. The results show that sustained policy support was accompanied by a strong rise in NEV share and an overall decline in both NO_2 and PM2.5. Correlation analysis shows a strong negative relationship between NEV share and pollutant concentrations. However, after the long-term time trend is added, the statistical significance of NEV share becomes weaker in the regression models. This suggests that the observed air-quality improvement should be understood within Shanghai's broader long-term environmental transition, rather than as the result of NEV promotion alone. Overall, the study provides a descriptive case analysis showing that policy support, vehicle structure change, and improvement in the most traffic-relevant pollution indicator moved in a broadly consistent way during the study period.

Keywords: New energy vehicles (NEVs), Vehicle electrification, Urban air pollution, Environmental policy, Air quality

1. Introduction

Urban air pollution remains a major challenge for sustainable urban governance, especially in large cities with heavy transport activity. As emissions from some stationary sources have gradually come under stricter control, traffic-related emissions have become a more important part of the urban pollution mix. Among major pollutants, NO_2 is especially important because it is more closely related to motor-vehicle emissions and contributes to the formation of secondary particulate matter. This makes transport transition an important entry point for understanding changes in urban air quality and for evaluating the environmental relevance of transport policy [1].

In this context, new energy vehicles (NEVs) are increasingly seen not only as an industrial or technological issue, but also as an environmental governance issue. NEV promotion is widely regarded as an important way to reduce traffic-related emissions and support greener urban transport systems. Existing studies suggest that the rapid growth of motor-vehicle ownership has increased

© 2026 The Authors. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

DOI: 10.54254/2753-8818/2026.AU34801

both congestion and air-pollution pressure in cities, while NEV expansion may help reduce these pressures [2]. Scenario-based evidence for China further suggests that large-scale electrification could substantially reduce both PM2.5 and NO_2 concentrations. This means that transport electrification may bring important environmental benefits in addition to industrial and energy benefits [3].

Shanghai is a particularly suitable case for examining this issue. As one of China's largest and most economically active cities, Shanghai faces strong transport demand, high vehicle intensity, and continued pressure for air-pollution control. At the same time, it has implemented one of the country's earliest and most sustained policy packages for NEV promotion, including purchase support, license-plate privileges, public-sector promotion, and charging-infrastructure development. Shanghai's license-plate incentives for NEVs operate within an auction-based conventional plate-control system. This gives NEV promotion a stronger influence on vehicle-purchase decisions than ordinary subsidy policies alone. These features make Shanghai a useful front-runner case in which policy intervention, vehicle structure change, and environmental governance are closely connected [4].

Existing studies have already shown the environmental relevance of NEV promotion. On the one hand, motor-vehicle emissions are an important source of urban air pollution. On the other hand, transport electrification can reduce direct traffic-related emissions and may therefore improve air quality [1, 3]. In this sense, the environmental value of NEV promotion is already widely recognized.

Research in this field has mainly developed in two directions. The first is policy-oriented evaluation, which examines whether pilot programs, subsidy schemes, or broader NEV promotion policies can improve urban air quality. Existing evidence suggests that China's NEV promotion policies can help improve urban air quality, and some studies find especially clear effects for NO_2 reduction [1, 2]. The second direction looks more directly at the relationship between electric-vehicle expansion or use and specific pollution indicators. Evidence from Beijing, Shanghai, and Shenzhen suggests that greater battery electric vehicle use is associated with overall air-quality benefits, although the response is not the same for all pollutants [5]. Some indicators improve, but NO_2 does not always show a simple and steady decline. This suggests that the environmental effects of transport electrification may differ across pollutants and urban contexts. At the same time, scenario-based studies continue to show that large-scale electrification could significantly reduce both NO_2 and PM2.5 at the national level, which further highlights the importance of this topic [3].

Despite these advances, three limitations remain. First, much of the existing literature focuses either on the relationship between policy and air quality or on the relationship between EV activity and air quality but gives less direct attention to vehicle structure change. Yet in a policy-sensitive case such as Shanghai, vehicle structure change is an important intermediate step through which sustained policy support may be reflected in environmental outcomes. Second, many studies use broad or composite indicators, while pollutants more directly linked to road traffic still need more focused discussion. In this respect, NO_2 should receive priority because it is more closely linked to vehicle emissions than PM2.5, whose sources are more complex and include industrial emissions, secondary formation, and regional transport [1, 5]. Third, the literature still lacks sufficient case-based discussion of leading cities such as Shanghai, where policy intervention has been strong, implementation has lasted for a long period, and the governance setting is highly distinctive [4, 5].

These gaps suggest the need for a case-based analysis that asks not whether NEV promotion has a separately identified causal effect in general, but whether policy support, vehicle structure change,

DOI: 10.54254/2753-8818/2026.AU34801

and traffic-related pollution indicators moved in a broadly consistent way within a specific urban context.

This study is motivated by the need to examine the environmental implications of NEV promotion through a more clearly structured case-based framework. Instead of treating policy and air quality as directly connected, it organizes the analysis around the sequence of policy support, vehicle structure change, and air-quality change. The aim is not to identify an independent causal effect of NEV promotion on air quality, but to examine whether these three dimensions changed in a temporally and directionally consistent way in Shanghai [6, 7].

Based on this motivation, the study addresses three questions. First, how did Shanghai's NEV promotion policies evolve during 2015–2024, and what broad stages can be identified in this process? Second, during this period, did the share of NEVs in the city's vehicle fleet increase substantially? Third, was this vehicle structure change descriptively consistent with changes in urban NO_2 concentration, with PM2.5 used as supporting evidence?

Accordingly, this paper is designed as a descriptive, consistency-oriented case study rather than a causal identification study. It does not attempt to isolate the net effect of NEV policies or to test each link through a strict mechanism analysis. Instead, it examines whether policy support, vehicle structure change, and air-quality change moved in a broadly consistent way over time. In this design, NO_2 is used as the primary environmental indicator because it is more directly linked to road traffic emissions, while PM2.5 provides supporting evidence for broader air-quality change [8-10].

2. Methods

2.1. Analytical framework and research design

This study adopts a descriptive, consistency-oriented framework to examine whether the environmental changes observed in Shanghai were broadly consistent with sustained NEV promotion and vehicle structure change. The analysis is organized around three dimensions: policy support, vehicle structure change, and air-quality change. The aim is not to identify a single causal effect through strict econometric methods, but to assess whether these three dimensions changed in a temporally and directionally consistent way during 2015–2024.

Based on this framework, the research proceeds in three steps. First, the study reviews the evolution of NEV promotion policies in Shanghai and identifies the main features of different policy stages. Second, it examines whether these policy stages were accompanied by vehicle structure change, especially growth in NEV ownership and a rising NEV share in the total vehicle fleet. Third, it compares changes in pollution indicators, focusing on NO_2 and using PM2.5 as supporting evidence, to assess whether their trends were broadly consistent with vehicle structure change.

This design has several clear boundaries. First, the analysis is limited to Shanghai as a front-runner case and should not be directly generalized to other cities. Second, the study is descriptive and consistency-oriented rather than designed for formal causal identification. Third, the main concern is whether vehicle structure change and air-quality change moved in a broadly consistent way, rather than whether an exact independent policy effect can be estimated. Within this framework, NO_2 is treated as the primary indicator because it is more closely linked to road traffic emissions, while PM2.5 is used as supporting evidence because it is affected by a wider range of sources and atmospheric processes.

DOI: 10.54254/2753-8818/2026.AU34801

2.2. Study area overview

Shanghai is located on the eastern coast of China and occupies a central position in the Yangtze River Delta, one of the country's most economically dynamic regions. As a major national transport hub, Shanghai has a highly developed urban system, intensive economic activity, and strong demand for both passenger and freight transport. The spatial scope of this study is the administrative area of Shanghai Municipality.

In terms of natural and socioeconomic conditions, Shanghai is characterized by flat terrain, a high level of urbanization, and a subtropical monsoon climate. Meteorological conditions such as wind speed and broader seasonal variation can affect the dispersion and accumulation of air pollutants. At the same time, the city's dense population and high traffic intensity make vehicle emissions an important part of the local pollution context. These features provide a relevant setting for examining the relationship between vehicle structure change and air-quality change.

Shanghai is also distinctive from a policy perspective. As one of China's earliest and most active cities in NEV deployment, it has implemented a wide range of policy instruments since the mid-2010s, including license-plate privileges, financial incentives, public-sector promotion, and charging-infrastructure expansion. The policy effect is especially notable because NEV plate privileges directly offset the high cost of acquiring conventional plates under Shanghai's auction-based control system. This makes the city particularly suitable for examining whether policy support, vehicle structure change, and air-quality change moved in a consistent way over time.

2.3. Data sources and preprocessing

This study uses three main types of data: policy data, vehicle data, and air-quality data. The first category is policy data. Official policy documents related to NEV promotion in Shanghai were collected mainly from the websites of the Shanghai Municipal People's Government, the Shanghai Municipal Development and Reform Commission, the Shanghai Municipal Transportation Commission, the Shanghai Municipal Commission of Economy and Informatization, and other relevant authorities. The collected documents were sorted by publication date. Duplicate releases, reposted materials, and documents not directly related to NEV promotion were excluded. Based on policy content, the documents were further classified into major policy-tool categories, including purchase incentives, license-plate privileges, public-sector promotion, and charging-infrastructure development. On this basis, the evolution of Shanghai's NEV policy framework was summarized and divided into stages according to broad changes in policy focus and implementation emphasis.

The second category is vehicle data. These data were obtained from official statistical and administrative sources, mainly including the Shanghai Statistical Yearbook, transport-related official reports, and publicly released government statistics on NEV ownership and total vehicle stock. During preprocessing, the original statistics from different sources were checked for consistency in statistical scope and converted to a unified annual scale. Absolute quantities were then transformed into structural indicators, especially the share of NEVs in total vehicle stock, because this study focuses on vehicle structure change rather than simple growth in NEV numbers.

The third category is air-quality data. The main environmental indicators are NO_2 and PM2.5 concentrations. NO_2 and PM2.5 concentrations are measured in $\mu g/m^3$. These data were collected from official environmental monitoring and reporting sources, including materials released by the Shanghai Municipal Bureau of Ecology and Environment and related environmental bulletins. To improve comparability, the analysis uses April–October mean concentrations rather than full-year means. This treatment reduces the influence of winter heating and stronger seasonal disturbance and

DOI: 10.54254/2753-8818/2026.AU34801

provides a more stable non-heating-season basis for comparison with annual changes in NEV share. During preprocessing, the pollution data were checked for missing values and organized into comparable annual series.

Because the study combines multiple data sources, temporal alignment is important. Policy data, vehicle data, and pollution data were organized within the common study period of 2015–2024 as far as data availability allowed. Based on major policy transitions and data continuity, the study established a comparative framework linking policy stage, vehicle structure change, and air-quality change.

2.4. Variables and indicators

To examine the relationship among NEV promotion, vehicle structure change, and air-quality change, this study organizes the variables into three groups: policy-related variables, vehicle-structure indicators, and air-quality indicators.

2.4.1. Figures

Policy-related variables are derived from official policy documents issued by the Shanghai Municipal People's Government and relevant administrative departments. These materials are used to identify the overall direction, main instruments, and changing priorities of Shanghai's NEV promotion policies during the study period. In this study, policy variables are not treated as quantitative regressors. Instead, they are used to describe the policy environment in which vehicle structure change occurred and to provide contextual evidence for the policy background of this process. The analysis therefore emphasizes policy continuity, policy orientation, and the broad expansion of policy tools, rather than constructing a formal numerical index of policy strength.

2.4.2. Vehicle-structure indicators

Vehicle-structure indicators form the central structural dimension in the analytical framework. The primary indicator is the share of NEVs in total vehicle stock, which captures the extent of transport electrification and vehicle structure change in Shanghai. As a proportional indicator, NEV share is more suitable than absolute NEV ownership for showing structural change in the urban vehicle fleet. It is defined as NEV Share = NEV ownership / total vehicle stock.

This indicator is preferred to absolute NEV numbers because it directly reflects changes in fleet composition. Where relevant, supporting information such as total NEV ownership is also used as auxiliary descriptive evidence.

2.4.3. Air-quality indicators

Air-quality indicators are used to assess whether vehicle structure change is associated with environmental improvement. Among them, NO_2 is treated as the primary indicator because it is more closely linked to road traffic emissions and is therefore more suitable for evaluating the atmospheric implications of transport electrification. In this study, NO_2 serves as the core outcome variable for judging whether vehicle structure change was descriptively consistent with improved air quality.

PM2.5 is used as a supporting indicator. Although it is also an important urban pollution measure, its sources are more complex and include traffic emissions, industrial emissions, secondary aerosol

DOI: 10.54254/2753-8818/2026.AU34801

formation, and regional transport. For this reason, PM2.5 is interpreted more cautiously and is used mainly as supporting evidence rather than as the decisive test of the analytical framework.

2.5. Analytical methods

Because different parts of the analytical framework play different roles in this study, they are examined using different descriptive approaches. The policy dimension is analyzed through stage-based qualitative comparison, while the relationship between vehicle structure change and air-quality change is examined through descriptive comparison and a simple supplementary regression test.

2.5.1. Descriptive assessment of the policy background

Given the lagged and cumulative nature of policy influence, this study does not estimate a contemporaneous statistical relationship between policy issuance and annual vehicle structure change. Instead, the policy dimension is examined descriptively by identifying whether Shanghai maintained sustained and explicit support for NEV promotion during the study period, and whether the policy system expanded over time in terms of major instruments and implementation focus. This part of the analysis is intended to establish the institutional background in which vehicle structure change occurred, rather than to estimate a separate policy effect.

2.5.2. Assessment of vehicle structure change and air-quality chang

The relationship between vehicle structure change and air-quality change is the core empirical focus of this study. The aim is to assess whether a cleaner vehicle structure, represented mainly by a rising NEV share, is associated with improved air quality, especially lower NO_2 concentrations.

This assessment is conducted in three steps. First, trend analysis is used to compare annual changes in NEV share and pollution indicators. This step examines whether continued vehicle structure change was accompanied by an overall decline in pollutant concentrations during the study period.

Second, annual scatter plots and Pearson correlation analysis are used to describe the relationship between NEV share and pollutant concentrations. The focus is April–October mean NO_2. This period is chosen to reduce seasonal noise. Although Shanghai is not located in a northern heating region, winter air quality is often affected by regional pollution transport and unfavorable meteorological conditions such as temperature inversions. Using April–October averages help reduce these external influences and better capture local traffic-related signals. These analyses are intended to show the direction and strength of association at the annual level rather than to establish causality.

Third, a simple regression analysis is used as a supplementary test. It examines whether the negative relationship between NEV share and April–October mean NO_2 remains after adding limited controls. The dependent variable is April–October mean NO_2, and the main explanatory variable is NEV share. Meteorological variables and a time trend are added in alternative models to test whether the relationship remains stable in direction. This regression is not intended to prove strict causality. It only provides additional evidence under a simple model setting. The results should be interpreted with caution, especially because the sample size is small and other factors, such as broader pollution-control measures and non-traffic emission sources, may also affect air quality.

DOI: 10.54254/2753-8818/2026.AU34801

3. Results

3.1. Policy evolution of NEV promotion in Shanghai

Shanghai maintained a continuous policy orientation toward NEV promotion during 2015–2024. Rather than relying on a single policy tool, it gradually developed a broader policy system covering purchase and use incentives, infrastructure support, and public-sector deployment. This policy evolution provides the institutional background for the later change in vehicle structure.

The policy process can be divided into four stages. Stage I (2015–2017) focused on initial incentives. Local subsidies, license-plate privileges, and early use incentives established the basic framework for NEV adoption; while charging and battery-swapping facilities were still at an early stage and public-sector application remained mainly pilot-based. Stage II (2018–2020) marked expansion and stronger support. Policy support became broader and more differentiated, with stronger subsidies, expanded infrastructure planning and supervision, and faster NEV adoption in buses, taxis, sanitation vehicles, and logistics fleets. Stage III (2021–2022) showed a more systematic form of promotion. Policy support extended beyond purchase to trade-in subsidies, battery recycling, after-sales service, and data governance, while infrastructure targets and management became clearer. Stage IV (2023–2024) emphasized higher-quality expansion. Policy attention shifted from direct purchase stimulation to replacement demand, safety, efficiency, intelligence, and more refined supervision, while NEV adoption continued to deepen in public-service fleets.

Across these stages, four policy tools were especially important. First, purchase and use incentives lowered the initial barrier to NEV adoption. Second, infrastructure support gradually moved from basic provision to smarter and more regulated management. Third, public-sector deployment expanded NEV use in segments where policy leverage was relatively strong. Fourth, broader governance measures improved the long-term operation of the NEV system. Overall, Shanghai's NEV promotion policy showed both continuity and stage-specific adjustment. The policy framework became more comprehensive over time and provided sustained policy support for the expansion of NEVs in the city's vehicle fleet (Table 1).

Table 1. Stage-based comparison of NEV promotion policies in Shanghai, 2015–2024

Stage	Period	Stage keyword	Purchase and use incentives	Infrastructure support	Public-sector deployment
Stage I	2015–2017	Initial incentives	Local subsidies, license-plate privileges, and early use incentives established the basic policy framework.	Charging and swapping facilities remained at an early supporting stage.	Public-sector application was mainly pilot-based, with initial NEV requirements for official vehicles.
Stage II	2018–2020	Expansion and support improvement	Subsidies were strengthened and differentiated, and commercial-use plate quotas and charging subsidies were introduced.	Infrastructure planning, subsidy support, and supervision mechanisms were expanded.	Electrification accelerated in buses, taxis, sanitation, and logistics fleets.

DOI: 10.54254/2753-8818/2026.AU34801

Table 1. (continued)

Stage III	2021–2022	Systematic promotion	Support was extended to trade-in subsidies, battery recycling, after-sales services, and data governance.	Infrastructure governance became more systematic, with clearer targets and smarter charging management.	Public-sector NEV deployment expanded further across multiple transport sectors.
Stage IV	2023–2024	High-quality expansion	Policy focus shifted from purchase stimulation to replacement demand and refined management.	Infrastructure policy emphasized safety, intelligence, efficiency, and stronger supervision.	Promotion deepened in buses, heavy trucks, taxis, and logistics fleets.

3.2. Vehicle-structure change under sustained policy support

To capture vehicle structure change, this study uses the share of NEVs in Shanghai's civilian vehicle fleet as the core indicator. Compared with NEV stock alone, this measure more directly reflects whether the vehicle fleet changed over time in a cleaner direction.

As shown in Figure 1, NEV share increased continuously from 1.96% in 2015 to 28.33% in 2024. The increase was gradual in the early years but became much more pronounced after 2020. This indicates that the observed change was not a temporary fluctuation, but a sustained structural shift in the vehicle fleet.

The stage-based comparison table further clarifies this pattern. In Stage I (2015–2017), NEV share rose by 2.25 percentage points, with a net increase of 100,000 vehicles. In Stage II (2018–2020), the share increased by 3.32 percentage points, with 184,000 additional vehicles. The structural change became more pronounced in Stage III (2021–2022), when NEV share rose by 5.32 percentage points and NEV stock increased by 336,000 vehicles. In Stage IV (2023–2024), NEV share increased by 5.66 percentage points, the largest gain among all stages, while NEV stock increased by 357,000 vehicles (Fig. 1).

Two points are clear. First, NEV share increased in every policy stage, which shows a stable direction of vehicle structure change. Second, the later stages contributed larger percentage-point gains, which suggests that this structural change became more substantial over time. This section does not claim that policy alone determined the observed change. Market development, technological progress, and broader industrial trends may also have contributed. Still, the coexistence of sustained policy support and continuous vehicle structure change provides a reasonable descriptive basis for treating policy as an important background condition for Shanghai's NEV expansion (Table 2).

DOI: 10.54254/2753-8818/2026.AU34801

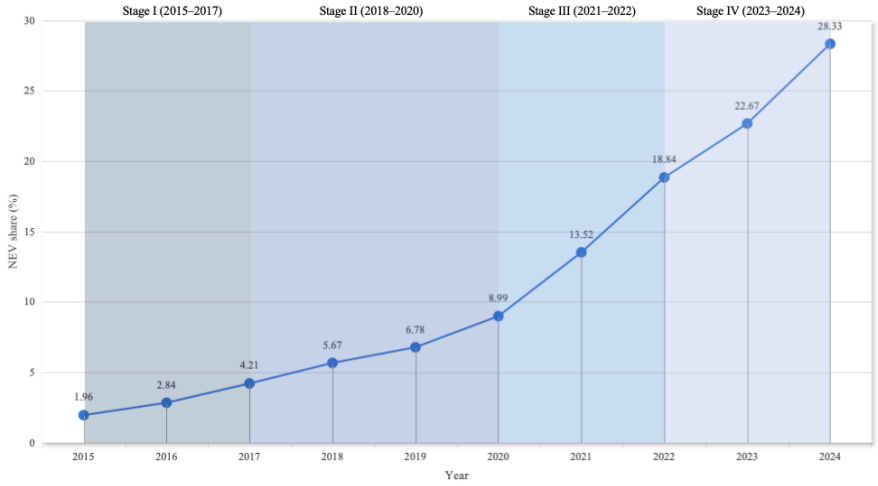


Figure 1. Change in the share of NEVs in Shanghai's civilian vehicle fleet, 2015–2024

Table 2. Stage-based comparison of NEV share growth in Shanghai, 2015–2024

Stage	Period	Initial NEV share (%)	Final NEV share (%)	Increase in NEV share (percentage points)	Net increase in NEV stock (10,000 vehicles)	Average annual growth rate of NEV stock (%)
Stage I	2015–2017	*1.96*	4.21	2.25	10.0	59.33
Stage II	2018–2020	5.67	8.99	3.32	18.4	32.92
Stage III	2021–2022	13.52	18.84	5.32	33.6	49.56
Stage IV	2023–2024	22.67	28.33	5.66	35.7	27.72

3.3. Air pollution trends under a transport-relevant indicator setting

In this study, NO_2 is treated as the primary air-quality indicator, while PM2.5 is used as a supporting indicator. NO_2 is selected as the primary indicator because it is more directly related to road traffic emissions. By contrast, PM2.5 is influenced by a wider range of factors, including industrial sources, secondary formation, regional transport, and meteorological conditions. It is therefore less suitable for representing the direct environmental response associated with vehicle structure change, but it still provides useful supporting evidence of broader air-quality change.

Figure 2 shows the trends of April–October mean NO_2 and PM2.5 concentrations over time. As shown in the figure, both April–October mean NO_2 and April–October mean PM2.5 declined overall during 2015–2024, while NEV share rose continuously over the same period. NO_2 showed a general downward trend, although the decline was not fully linear. PM2.5 also declined overall, with some fluctuations in the later years. At this stage, these patterns are used only to establish the descriptive background for the next section and do not imply direct causality.

Overall, the indicator setting used here provides a suitable basis for the following consistency analysis. NO_2 serves as the main traffic-related indicator, PM2.5 provides supporting evidence, and both pollutant series show an overall decline under the April–October framework.

DOI: 10.54254/2753-8818/2026.AU34801

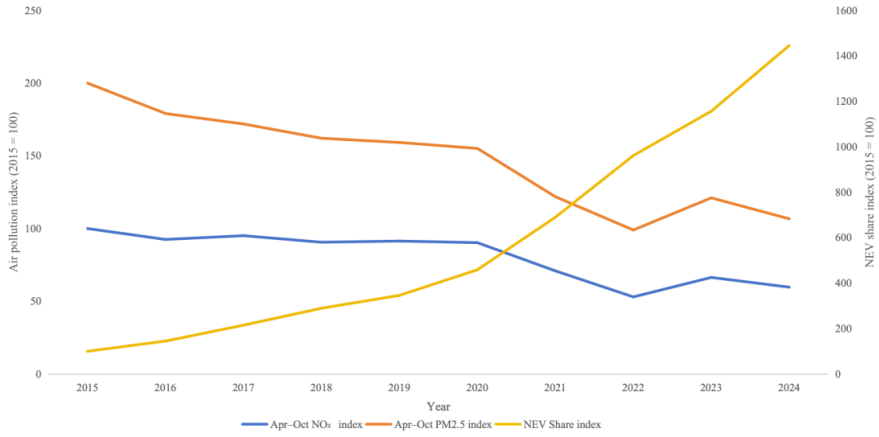


Figure 2. Indexed trends of April–October mean NO_2, April–October mean PM2.5, and NEV share in Shanghai, 2015–2024 (2015 = 100)

3.4. Main descriptive evidence: consistency between vehicle-structure change and NO_2 improvement

Because NO_2 is the most traffic-relevant pollution indicator in this framework, the relationship between vehicle structure change and NO_2 is treated as the main environmental focus of the analysis.

Figure 3 compares annual NEV share with April–October mean NO_2 concentrations from 2015 to 2024. The two series show a broad opposite movement over time: NEV share increased substantially, while NO_2 generally moved downward. Although NO_2 showed some short-term fluctuations, especially in the later years, its overall direction remained downward during the study period. At the descriptive level, this suggests that vehicle structure change and NO_2 improvement were broadly consistent in direction in Shanghai.

Figure 4 provides additional annual-level evidence through a scatter plot of NEV share and April–October mean NO_2. The fitted line slopes downward, which indicates that years with higher NEV share tended to have lower NO_2 concentrations. Table 3 further reports the Pearson correlation results. The correlation between NEV share and April–October mean NO_2 is strongly negative ($r = -0.916$, $p = 0.0002$), while the corresponding relationship for PM2.5 is also negative but somewhat weaker ($r = -0.852$, $p = 0.0018$). These results are consistent with the patterns shown in the figures and suggest a clear annual-level inverse relationship, especially for NO_2 (Table 3).

These findings should still be interpreted as descriptive evidence of consistency rather than strict causality. Because both NEV share and pollutant concentrations show strong long-term trends, the observed correlations may partly reflect broader temporal co-movement. For this reason, the correlation results are used here as supplementary statistical evidence within a descriptive framework, while the regression analysis in Section 3.6 provides a more cautious check after limited controls are introduced.

DOI: 10.54254/2753-8818/2026.AU34801

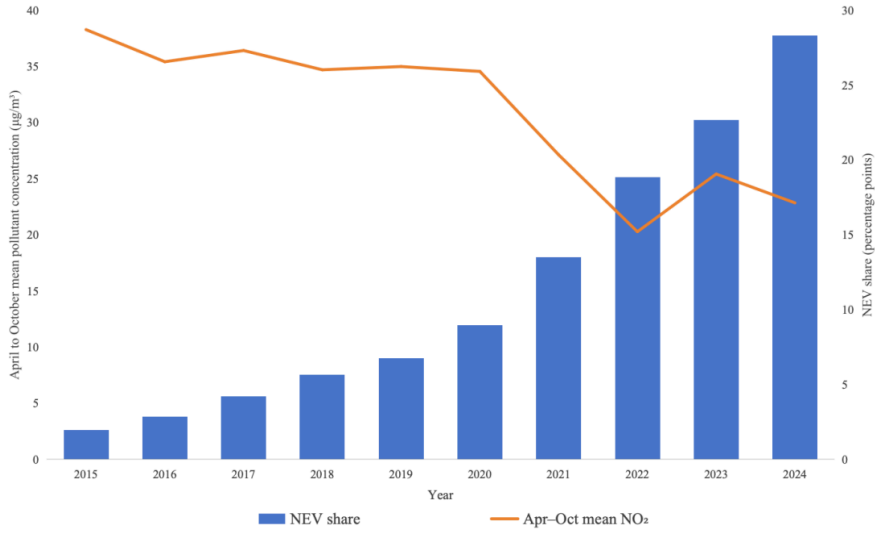


Figure 3. Comparison of annual NEV share and April–October mean NO_2(μg/m³) concentration in Shanghai, 2015–2024

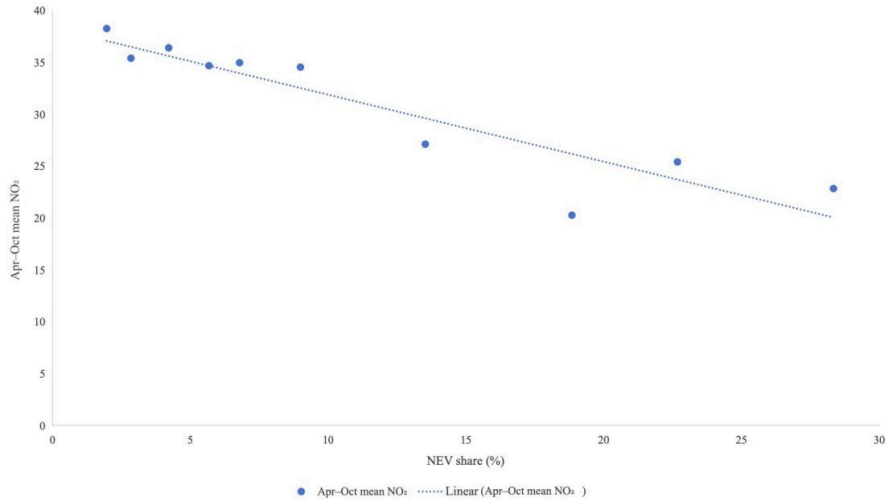


Figure 4. Relationship between NEV share and April–October mean NO_2(μg/m³) concentration in Shanghai, 2015-2024

Table 3. Pearson correlation between NEV share and April–October mean pollutant concentrations in Shanghai, 2015–2024

Variable pair	Pearson r	p-value
NEV share vs Apr–Oct mean NO_2	-0.916	0.0002
NEV share vs Apr–Oct mean PM2.5	-0.852	0.0018

3.5. Supplementary evidence from PM2.5

PM2.5 is used only as a supporting indicator in this study. As shown in Figure 5 and the correlation results reported in Table 3, PM2.5 also shows a broadly negative relationship with NEV share.

DOI: 10.54254/2753-8818/2026.AU34801

However, compared with NO_2, PM2.5 is less specific to traffic emissions and is more strongly influenced by non-transport factors. For this reason, it cannot serve as the main indicator for evaluating the relationship between vehicle structure change and air-quality change.

Even so, April–October mean PM2.5 also declined overall during 2015–2024, while NEV share increased continuously over the same period. In this sense, PM2.5 shows a broadly consistent pattern under the background of vehicle structure change. Its role, however, is supporting rather than central. The main environmental interpretation of this study therefore remains based on NO_2.

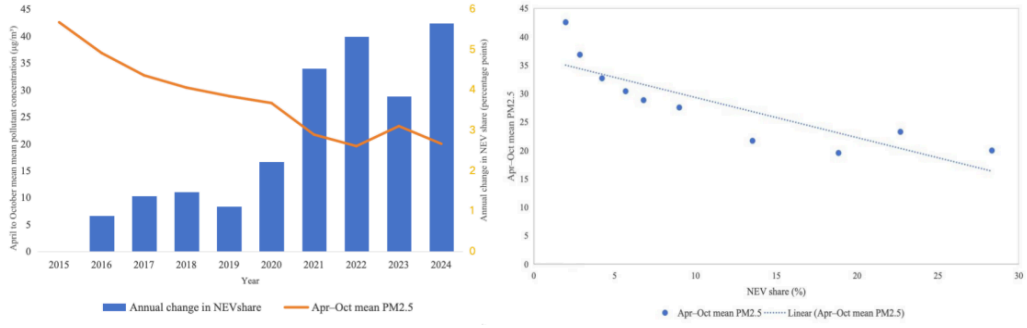


Figure 5. Relationship between NEV share and April–October mean PM2.5 concentration (μg/m³) in Shanghai, 2015–2024

3.6. Regression-based supplementary test of the relationship between NEV share and NO_2

To complement the descriptive analysis, this section uses a simple regression test to examine the relationship between NEV share and April–October mean NO_2. The aim is not to identify a strict causal effect, but to assess whether the negative relationship remains visible under several basic model settings.

The dependent variable is April–October mean NO_2 concentration, and the main explanatory variable is NEV share in Shanghai's civilian vehicle fleet. April–October averages are used to maintain consistency with the earlier descriptive analysis and to reduce the influence of stronger winter seasonal disturbance. NO_2 is selected as the dependent variable because it is more directly related to traffic emissions than broader composite indicators, while NEV share is used as the core explanatory variable because the main concern of this study is whether a cleaner vehicle structure was descriptively associated with lower traffic-related pollution levels.

Because the annual sample is small, the regression specification is kept parsimonious to reduce the risk of overfitting and unstable estimates. Wind speed is included as a basic meteorological control because it is directly related to pollutant dispersion. Other potentially relevant factors, such as additional meteorological variables and short-term disturbance indicators, are not included at the same time in the baseline models because the sample is too limited to support a more heavily parameterized design. Their exclusion should therefore be understood as a modeling constraint rather than a sign that they are unimportant. The regression models are specified as follows: $NO_2 = \alpha + \beta_1 NEV\ share + \varepsilon$; $NO_2 = \alpha + \beta_1 NEV\ share + \beta_2 Wind + \varepsilon$; and $NO_2 = \alpha + \beta_1\ NEV\ share + \beta_2 Wind + \beta_3 Trend + \varepsilon$. These models progressively incorporate meteorological conditions and temporal trends to examine the relationship between NEV share and NO_2 concentrations. Model 1 includes only NEV share. Model 2 adds April–October mean wind speed as a basic meteorological control. Model 3 further adds a time trend as a supplementary sensitivity check. In this study, the model with a time trend is not treated as the single preferred specification, because in a short annual series the time trend may absorb part of the same long-run movement that is also reflected in the rise of NEV share.

DOI: 10.54254/2753-8818/2026.AU34801

The results show that the coefficient of NEV share is negative in all three models. In Model 1, the coefficient is negative and statistically significant. In Model 2, it remains negative and significant after wind speed is added. These results are consistent with the earlier trend and correlation analysis.

A different pattern appears in Model 3. After the time trend is included, the coefficient of NEV share remains negative but is no longer statistically significant. This result is important. It suggests that part of the negative relationship observed in the simpler models may reflect broader long-term co-movement between rising NEV share and declining NO_2, rather than a clearly separable independent effect of NEV share alone. In this sense, the regression results support a directionally consistent relationship between vehicle structure change and NO_2 improvement, but they do not provide evidence of a clearly identified independent effect of NEV share alone.

Overall, the regression analysis provides supplementary support for the argument that vehicle structure change was descriptively associated with improved NO_2 outcomes during the study period. At the same time, the results remain sensitive to long-term trend adjustment and should therefore be interpreted cautiously, especially given the small annual sample and the possible influence of broader pollution-control measures, regional transport, and other non-traffic emission sources.

In addition, the COVID-19 and post-pandemic period likely introduced substantial disturbance into this short annual series. Because 2020–2023 accounts for a large share of the sample period and also overlaps with the fastest phase of NEV expansion, part of the observed relationship between NEV share and NO_2 may reflect pandemic-related changes in mobility, traffic intensity, and urban emissions rather than vehicle structure change alone (Table 4).

Table 4. Regression results

Variables	Model 1***	Model 2***	Model 3
NEV share (%)	-0.646	-0.639	-0.148
	(0.100)	(0.097)	(0.364)
Apr–Oct mean wind speed		-2.338	-3.818
		(1.822)	(2.015)
Time trend			-1.531
			(1.100)
Constant	38.362	67.281	88.489
	(1.433)	(22.578)	(26.105)
Observations	10	10	10
R^2	0.838	0.889	0.901
Adjusted R^2	0.818	0.832	0.851

3.7. Integrated interpretation of policy support, vehicle structure change, and air-quality change

Taken together, the evidence supports a cautious descriptive interpretation of policy support, vehicle structure change, and air-quality change in Shanghai during 2015–2024. First, Shanghai maintained a relatively continuous and gradually strengthened policy orientation toward NEV promotion. Second, under this policy background, the structure of the civilian vehicle fleet changed substantially, with NEV share rising from a marginal level to a much more important part of the fleet. Third, during the same period, the selected pollution indicators showed an overall decline

DOI: 10.54254/2753-8818/2026.AU34801

under the April–October framework. Among them, NO_2 provides the strongest environmental evidence because it is more directly related to road traffic emissions. Time-series comparison, annual scatter analysis, and the simpler regression specifications all point to a broadly consistent relationship between higher NEV share and lower NO_2 concentrations. PM2.5, although less specific, shows a similar overall decline and therefore provides supporting background evidence.

The contribution of this study lies in organizing these three dimensions within a single descriptive framework and showing that they moved in a broadly consistent way over time. Sustained policy support was accompanied by a structural rise in NEVs, and this vehicle structure change was descriptively consistent with improvement in the most traffic-relevant pollution indicator. At the same time, the evidential weight of the three dimensions is not the same. The policy dimension provides contextual background, PM2.5 offers supporting evidence, and the main empirical pattern comes from the relationship between NEV share and NO_2.

This interpretation should remain limited. The results do not imply that policy automatically produced vehicle structure change, or that vehicle structure change alone directly caused the observed air-quality improvement. Rather, they support a more limited conclusion: during 2015–2024, policy support, vehicle structure change, and improvement in NO_2 moved in a temporally and directionally consistent way in Shanghai.

3.8. Limitations and boundaries of inference

The findings of this study should be interpreted within a clear inferential boundary. For the policy dimension, this study does not identify the separate effect of each policy instrument. The policy analysis is stage-based and descriptive and is intended to show that a sustained policy background for NEV expansion existed.

For the relationship between vehicle structure change and NO_2, the evidence supports descriptive consistency rather than strict causality. NO_2 concentrations are affected not only by vehicle structure, but also by meteorological conditions, broader emission-control measures, traffic activity, and other urban factors. Although the regression analysis includes limited controls, the annual sample remains small and cannot support strong causal identification.

The role of PM2.5 is also limited. Because it reflects multiple sources and atmospheric processes, it cannot serve as a direct indicator of traffic-related effects. Its role in this study is only supporting. There are also data and method limitations. The analysis is conducted at the annual scale, which limits the number of observations. The April–October averaging framework improves comparability, but it cannot fully remove seasonal and meteorological influences. This design is suitable for examining long-term patterns, but less suitable for identifying short-term dynamics or independent causal effects.

Another important limitation is the influence of the COVID-19 and post-pandemic period. Because the annual sample covers only ten years, the disruption associated with 2020–2023 occupies a substantial part of the study period. This is especially important because the most rapid increase in NEV share also occurred during and after this period. As a result, changes in traffic activity, mobility restrictions, economic fluctuation, and subsequent recovery may have affected pollutant concentrations in ways that are difficult to separate from the environmental implications of vehicle structure change in a short annual series.

For these reasons, the main contribution of this study is not to establish a strict causal relationship. Instead, it provides a bounded descriptive case analysis. The results suggest that Shanghai's NEV expansion was broadly consistent with improvement in traffic-related air quality, especially NO_2, while remaining within a cautious interpretive framework.

DOI: 10.54254/2753-8818/2026.AU34801

4. Conclusions

This study shows that Shanghai's NEV promotion during 2015–2024 followed a relatively continuous and gradually strengthened policy process, which provided an important institutional background for vehicle structure change. Under this policy context, the share of NEVs in Shanghai's civilian vehicle fleet increased substantially. This indicates a sustained structural change rather than a temporary market fluctuation.

During the same period, April–October mean NO_2 and PM2.5 both declined overall, while NEV share rose continuously. Among these indicators, NO_2 provides the strongest environmental evidence because it is more directly linked to road traffic emissions. The comparison of annual trends, the annual-level negative relationship, and the supplementary regression results together suggest that vehicle structure change was descriptively consistent with NO_2 improvement in Shanghai. PM2.5 showed a similar overall downward trend, but its interpretive value is more limited because it is less specific to traffic emissions.

Overall, the evidence suggests that policy support, vehicle structure change, and air-quality change moved in a broadly consistent way in Shanghai. The main contribution of this study is therefore not to establish strict causality, but to provide a descriptive, consistency-oriented case analysis showing that sustained policy support, vehicle structure change, and improvement in the most traffic-relevant pollution indicator evolved in a broadly consistent way over time.

Future research could strengthen and extend the present study in several ways. First, higher-frequency data, such as monthly NEV registration or stock data, would allow a more detailed examination of the temporal relationship between vehicle structure change and air-quality change, while also improving the empirical basis of the analysis. Second, a richer control framework could be introduced by incorporating additional meteorological variables, traffic-activity indicators, and other policy-related factors. This would help distinguish the specific contribution of vehicle structure change from broader co-occurring changes. Third, the vehicle-structure dimension could be refined further by distinguishing among different vehicle categories, such as private cars, buses, taxis, logistics vehicles, and heavy-duty vehicles, since the environmental significance of electrification is likely to differ across segments. Fourth, future studies could add a spatial perspective by comparing districts, monitoring sites, or areas with different levels of NEV adoption. This would help reveal whether the relationship between vehicle structure change and NO_2 is stronger in places where NEV adoption is more concentrated. Finally, more policy-oriented research could examine the different roles of specific policy instruments, such as purchase incentives, license-plate privileges, infrastructure support, and public-sector fleet replacement, to better clarify the internal structure of the policy environment behind vehicle structure change.

References

[1] R. Tan, D. Tang, B. Lin. (2018). Policy impact of new energy vehicles promotion on air quality in Chinese cities. Energy Policy, 118, 33–40. https: //doi.org/10.1016/j.enpol.2018.03.018

[2] Y. Xie, D. Wu, S. Zhu. (2021). Can new energy vehicles subsidy curb urban air pollution? Empirical evidence from pilot cities in China. Sci. Total Environ, 754, 142232. https: //doi.org/10.1016/j.scitotenv.2020.142232

[3] L. Wang, X. Chen, Y. Zhang, et al (2021). Switching to electric vehicles can lead to significant reductions of PM2.5 and NO_2 across China. One Earth, 4, 1037–1047. https: //doi.org/10.1016/j.oneear.2021.06.008

[4] Shanghai Municipal People's Government, Shanghai 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through 2035 (2021).

[5] W. Lyu, Y. Hu, J. Liu, et al. (2024). Impact of battery electric vehicle usage on air quality in three Chinese first-tier cities. Sci. Rep., 14, 21. https: //doi.org/10.1038/s41598-023-50745-6

DOI: 10.54254/2753-8818/2026.AU34801

[6] X. Hu, N. Chen, N. Wu, B. Yin. (2021). The potential impacts of electric vehicles on urban air quality in Shanghai City. Sustainability, 13(2), 496. https: //doi.org/10.3390/su13020496
[7] S. Zhang, Y. Jiang, S. Zhang, E. F. Choma. (2024). Health benefits of vehicle electrification through air pollution in Shanghai, China. Sci. Total Environ. 914, 169859. https: //doi.org/10.1016/j.scitotenv.2023.169859
[8] Y. Zhu, Y. Liu, X. Liu, H. Wang. (2023). Carbon mitigation and health effects of fleet electrification in China's Yangtze River Delta, Environ. Int. 180, 108203. https: //doi.org/10.1016/j.envint.2023.108203
[9] W. Ke, S. Zhang, Y. Wu, B. Zhao, S. Wang, J. Hao. (2017). Assessing the future vehicle fleet electrification: The impacts on regional and urban air quality, Environ. Sci. Technol., 51(2), 1007–1016. https: //doi.org/10.1021/acs.est.6b04253
[10] H. Huo, Q. Zhang, M. Q. Wang, D. G. Streets, K. He. (2010) Environmental implication of electric vehicles in China. Environ. Sci. Technol. 44, 4856–4861. https: //doi.org/10.1021/es100520c