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Research Article

Electric Vehicle Fleet Penetration and Air Pollution Mortality in Europe

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The transition to electric vehicles is widely promoted as contributing to the reduction of urban air pollution and climate change. This study examines the correlation between electric vehicle fleet penetration and premature deaths from air pollution (PM2.5 exposure) across 28 European countries. Using 2023-2024 data on actual vehicle fleet composition (not sales), we find a statistically significant negative correlation (r = -0.465, p = 0.013). Nordic countries show high EV penetration (Norway 28%, Denmark 12.1%) with low mortality rates (6.6 and 18.3 deaths per 100,000 respectively), while Eastern European countries exhibit <1% EV penetration with 70-145 deaths per 100,000. This result was expected for several reasons, the main one being that car exhaust is a major factor in air pollution in urban areas, but not the only one. In addition, geographic and meteorological factors dominate pollution patterns, while many countries bundle vehicle electrification with comprehensive policies addressing all emission sources. These findings, however, prove that electric vehicles have a positive effect on air quality and reduce mortality. The replacement of internal combustion engine vehicles with electric ones must proceed as fast as possible in order to reduce pollution-related mortality, but it must be coupled with other pollution abatement measures.

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Introduction

The European Union has set ambitious targets for vehicle electrification, requiring zero CO_2 emissions from new passenger cars by 2035. This policy is motivated by dual goals: climate change mitigation and urban air quality improvement. Fine particulate matter (PM2.5) from transportation contributes significantly to air pollution, with the European Environment Agency estimating over 180,000 premature deaths annually in the EU attributable to PM2.5 exposure above WHO guidelines.

Battery electric vehicles (BEVs) are a fundamental element of the EU policy, but their adoption varies dramatically across Europe. Norway leads with 28% of its passenger car fleet being BEVs as of 2024, while most Eastern European countries remain below 1% fleet penetration. This variation provides a natural testing ground to examine the relationship between EV adoption and air pollution health outcomes.

Of course, the relationship between EV adoption and air quality is complex and mediated by multiple factors: fleet turnover rates (typically 15-20 years), the relative contribution of vehicles versus other emission sources (residential heating, industry, agriculture), meteorological and geographic conditions affecting pollutant dispersion, and the comprehensiveness of environmental policy beyond just transportation. Yet, the results of this study show that BEVs do reduce mortality in urban areas in Europe. These results for Europe broadly agree with those recently found for China.[1]

Methods

Data Sources

Air pollution mortality data were obtained from the European Environment Agency (EEA)[2] estimates of premature deaths attributable to PM2.5 exposure above 5 μg/m³, the threshold established in the WHO[3] air quality guidelines. Data are expressed as deaths per 100,000 inhabitants aged 30 years and above. Electric vehicle fleet data represent the actual percentage of battery-electric vehicles in the total passenger car fleet as of 2024, sourced from ACEA (European Automobile Manufacturers' Association) reports[4]. These data reflect accumulated vehicle stock, not annual sales, providing a more accurate measure of actual fleet electrification. For countries lacking comprehensive ACEA fleet data, estimates were derived from cumulative registration data and typical fleet turnover patterns. Although mortality data are from 2023 and fleet data from 2024, the one-year offset is negligible given the slow temporal dynamics of both variables and the cross-sectional nature of the analysis examining spatial rather than temporal variation.

Statistical Analysis

Pearson correlation coefficients were calculated between EV fleet percentage and PM2.5 mortality rates across 28 European countries (EU member states, EFTA countries, and several Balkan nations). Statistical significance was assessed at $\alpha = 0.05$. Linear regression was used to visualize the relationship trend,

though we recognize the relationship may not be strictly linear given the complex causal pathways involved.

Results

Air Pollution Mortality Patterns

Figure 1 shows the distribution of PM2.5-attributable deaths across Europe. Nordic countries (Finland 0.9, Sweden 3.0, Norway 6.6, Denmark 18.3 deaths per 100,000) demonstrate the lowest mortality rates, while Balkan countries exhibit the highest (North Macedonia 222.2, Bosnia and Herzegovina 199.0, Albania 196.1). The EU average is 56.8 deaths per 100,000.
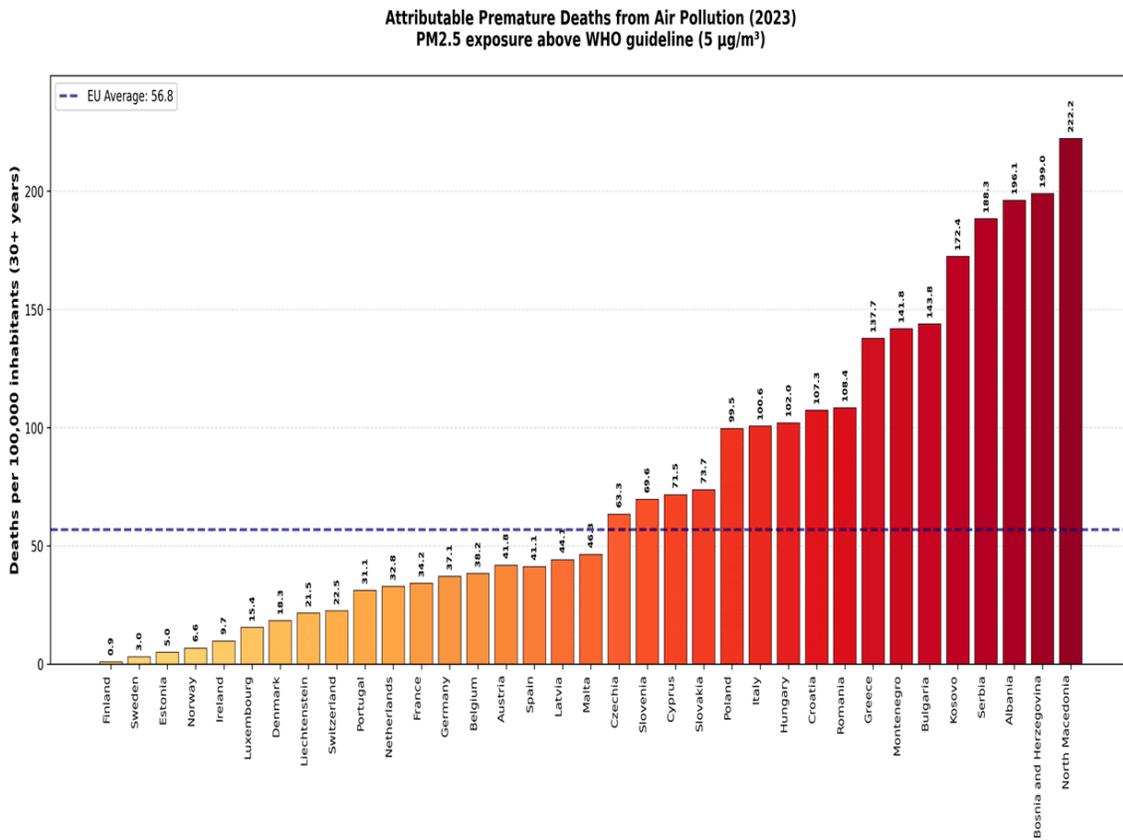

Figure 1. *Attributable premature deaths from PM2.5 air pollution per 100,000 inhabitants (30+ years) across European countries, 2023.*

EV Fleet Penetration and Air Quality Correlation

Figure 2 presents the correlation between actual EV fleet penetration (percentage of all passenger cars on the road) and PM2.5 mortality rates. The analysis reveals a statistically significant negative correlation (Pearson r = –0.465, p = 0.013), indicating that countries with higher EV fleet penetration tend to have lower air pollution mortality rates.

The correlation strength is moderate, as it should be expected since EVs are not the only cause of air pollution in Europe. Norway represents the strongest performer with 28% fleet electrification and 6.6 deaths per 100,000. Denmark, despite 12.1% EV fleet share, shows 18.3 deaths per 100,000 – nearly three times Norway's rate. Eastern European countries cluster at <1% EV penetration with 70-145 deaths per 100,000.
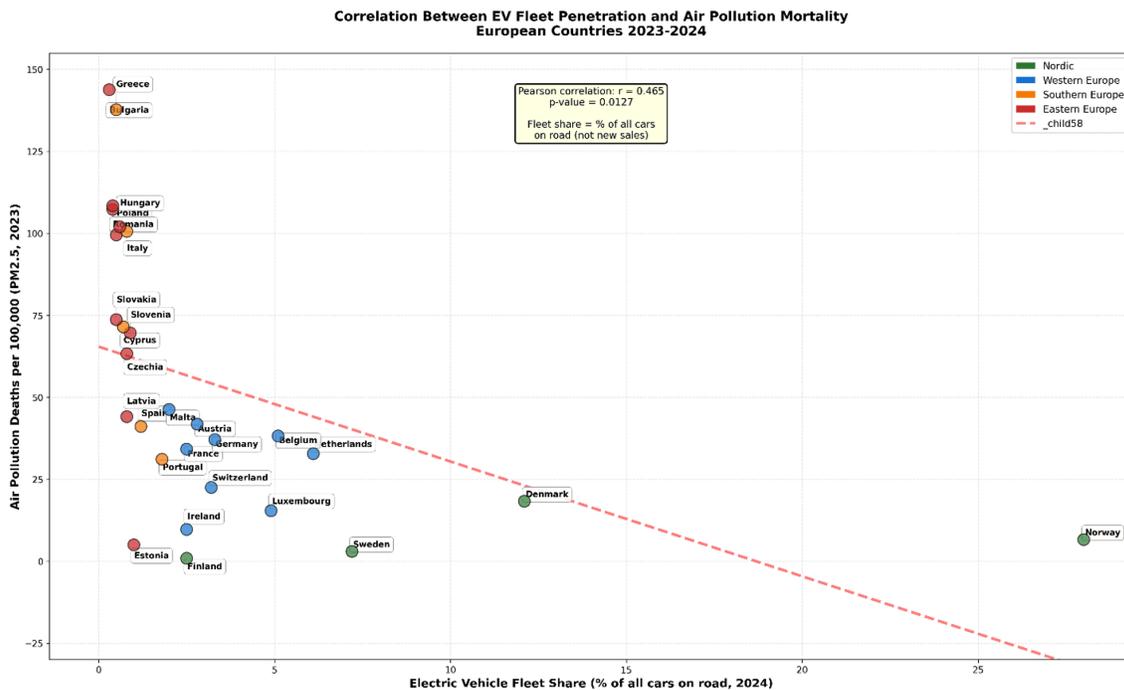

Figure 2. *Correlation between electric vehicle fleet penetration (% of total passenger cars) and PM2.5 mortality rates across European countries, 2024. Colors indicate geographic regions: Nordic (green), Western Europe (blue), Southern Europe (orange), Eastern Europe (red).*

Discussion

The moderate correlation strength reflects fleet turnover lag. Even countries with aggressive EV sales policies (e.g., Denmark with 55% of new car sales being BEVs in 2024) achieve only 12.1% actual fleet penetration due to the slow replacement of existing vehicles. With typical passenger car lifespans of 15–20 years in Europe, even sustained high EV sales rates translate slowly into fleet composition changes.

This lag effect creates a multi-decadal transition period during which the majority of vehicles remain combustion-powered. Sweden, despite 7.2% fleet electrification representing two decades of accumulated adoption, still has 93% of its fleet as conventional vehicles.

PM2.5 emissions derive from multiple sources beyond transportation. In Eastern Europe, residential coal and wood heating dominate emission profiles. Poland's 0.5% EV fleet share is essentially irrelevant to air quality when coal furnaces remain the primary heating source. Italy's persistently high mortality rate (100.6 deaths per 100,000) despite being a wealthy EU member reflects extensive wood stove usage for residential heating, particularly in rural areas.

Agricultural burning, industrial emissions, and cross-border pollution transport further complicate the causal pathway from vehicle electrification to air quality improvement. Even complete vehicle fleet electrification would leave these other sources unaddressed.

Geographic factors also create systematic patterns largely independent of policy choices. The Po Valley in Northern Italy traps pollutants due to topographic basin effects and frequent atmospheric inversions. Balkan mountain valleys similarly concentrate emissions regardless of source. Conversely, Nordic countries benefit from Atlantic wind patterns that disperse pollutants effectively.

Denmark's relatively high mortality rate (18.3 per 100,000) despite 12.1% EV penetration partially reflects continental European weather patterns that occasionally trap pollution, unlike Norway's more consistent Atlantic ventilation. These meteorological differences create ceiling and floor effects on achievable air quality improvements.

The most successful countries in both EV adoption and air quality demonstrate comprehensive environmental policy portfolios. Norway's low mortality rate reflects not just vehicle electrification but also district heating systems powered by hydroelectric generation, strict industrial emission standards, and effective agricultural waste management. Vehicle electrification serves as a marker of overall environmental governance quality rather than being independently causal.

This represents a classic systemic insight: complex problems rarely yield to single–lever solutions. From this perspective, the moderate correlation between EV penetration and air quality is exactly what systems thinking would predict – vehicle electrification is necessary but insufficient, and must be bundled with complementary policies addressing all emission sources.

These findings have important implications for energy transition strategy. First, the fleet turnover lag means that even aggressive EV adoption policies require 15–20 years to substantially affect fleet composition and air quality. This multi–decadal timeline must inform public expectations and policy persistence.

Second, vehicle electrification alone cannot solve air quality crises in countries where transportation is not the dominant PM2.5 source. Poland, for instance, would see minimal air quality improvement from vehicle electrification without addressing residential coal heating. This suggests regionally-differentiated transition strategies based on local emission source profiles.

Third, the success of Nordic countries in achieving both high EV penetration and low mortality rates demonstrates the value of comprehensive, multi–sector environmental policy. Rather than treating vehicle electrification as a standalone solution, it must be integrated into broader strategies addressing heating, industry, agriculture, and electricity generation simultaneously.

Limitations

This analysis has several limitations. First, fleet penetration data for some countries required estimation based on sales patterns and typical turnover rates, introducing measurement uncertainty. Second, the cross-sectional design cannot establish causality – the correlation could reflect confounding by overall governance quality or economic development. Third, PM2.5 mortality estimates themselves carry uncertainty, particularly in countries with less developed monitoring networks.

Fourth, this analysis does not account for electricity generation mix. Countries charging EVs primarily with coal-fired power may see smaller air quality benefits than those with cleaner grids, though urban health impacts remain positive due to emission displacement from cities to power plants.

Conclusions

Electric vehicle fleet penetration shows a statistically significant, although moderate, negative correlation with air pollution mortality across European countries (r = –0.465, p = 0.013). This relationship

is mediated by fleet turnover lag, multi-source emission dynamics, geographic factors, and policy comprehensiveness.

From a systemic perspective, these findings illustrate the limitations of single-lever interventions in complex socio-technical systems. Vehicle electrification represents a necessary component of air quality improvement but cannot independently solve pollution crises. Successful countries bundle vehicle policies with comprehensive approaches to residential heating, industrial emissions, and agricultural practices.

The multi-decadal fleet turnover timeline means that even aggressive EV adoption policies require sustained commitment over 15-20 years to substantially affect air quality. Policymakers must manage public expectations accordingly while simultaneously addressing non-transportation emission sources to achieve meaningful mortality reduction in the near term.

The 246-fold difference in mortality rates between best (Finland, 0.9 per 100,000) and worst (North Macedonia, 222.2 per 100,000) performing countries demonstrates that substantial improvement is achievable. However, achieving Nordic levels of air quality requires comprehensive environmental policy extending well beyond vehicle electrification alone.

Statements and Declarations

References

1. ^Su, Diao (2025). "Assessing the Causal Effect of Air Pollution on Electric Vehicle Adoption Using Real World Data: Evidence from 270 Chinese Cities." J Transp Geogr. **124**:104120.

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Declarations