TIL 6022 — Python Programming Project

Group 16

An analysis of the impact of electric vehicles on emission intensity in Dutch road transport

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Introduction

The electrification of passenger transport plays a central role in achieving national climate, reducing emissions, and improving air quality (Tamba et al., 2022). Since 2018, the share of electric passenger cars (Battery Electric Vehicles, BEVs) has increased rapidly (ACEA, 2019). At the same time, the transport sector faces the challenge to not only reduce carbon dioxide emissions, but also air pollution such as nitrogen oxides (NOx) and particulate matter (PM10) (EEA, 2024).

This study investigates to what extent the growth of electric passenger cars in the Netherlands between 2018 and 2023 has contributed to changes in CO2, NOx and PM10 emissions. It analyses both total emissions (million kg) and emission intensities (g/km), assessing how they evolved over time and how they related to BEV sales. In addition, it explores whether NOx and PM10 intensities declined faster than CO2 intensity, and whether the results remain robust when excluding 2020, the pandamic year that disrupted traffic volumes.

The analysis is based on three national datasets covering the years 2018-2023, containing detailed information on newly sold passenger cars, total kilometres driven in the Netherlands, and emissions per pollutant.

By linking emission developments to the rise of electric vehicles, the study provides insight into the effectiveness of vehicle electrification in reducing climate and air-pollution impacts from passenger transport in the Netherlands.

Research question

Main research question:

To what extent has the growth of electric passenger cars in the Netherlands between 2018 and 2023 correlated to changes in CO_2, NOx and PM10 emissions from passenger cars, both in totals and per vehicle-kilometre?

Sub-questions:

- How do CO_2, NOx, and PM10 totals and intensities (g/km) for passenger cars evolve over 2018–2023?
- How does the BEV, FCEV, PHEV (passenger–car) population develop during the period 2018–2023?
- How are BEV, FCEV, PHEV (passenger–car) changes related to annual emission intensities?
- How might the long–term growth in EV share affect emission intensity by 2030?

Sub-question 1

Between 2018 and 2023, total emissions from passenger cars in the Netherlands show a clear downward trend for all three pollutants. This is shown in figure 1 and table 1.

CO2 emissions decrease from roughly 17.5 to 15.6 million kg, while NOx falls from about 28.8 to 18.7 million kg, and PM10 remains relatively stable around 2.0 million kg. In the figure of CO2 and PM10 the sharp decline in 2020 coincides with the COVID-19 pandemic, which led to widespread lockdowns, remote working, and reduced travel activity in the Netherlands. As a result, the total number of kilometres driven by passenger cars fell by nearly 15-20% compared to previous years. This reduction in mobility is directly translated into lower total emissions, rather than a structural improvement in vehicle efficiency or technology.

Figure 1. Passenger cars: total emissions per year (2018–2023)

Table 1: Total kilometres driven, total emissions, and emission intensities (g/km) for passenger cars in the Netherlands (2018–2023).

Year	Total kilometres (mln km)	CO_2 (mln kg)	NOx (mln kg)	PM_{10} (mln kg)	CO_2 intensity (g/km)	NOx intensity (g/km)	PM_{10} intensity (g/km)

2018	109,337.4	17,487	28.79	2.25	159.94	0.263	0.0206
2019	109,086.8	17,230	26.73	2.19	157.95	0.245	0.0201
2020	91,723.0	14,302	19.58	1.81	155.93	0.213	0.0197
2021	96,988.8	14,874	19.15	1.90	153.36	0.197	0.0196
2022	102,679.6	15,374	18.90	2.00	149.73	0.184	0.0195
2023	107,143.1	15,638	18.66	2.08	145.95	0.174	0.0194

When emissions are normalized by kilometers driven, a clear downward trend can be observed for CO2 and NOx intensities between 2018 and 2023. This is shown in figure 2. This indicates that both technological improvements and the gradual increase in electric vehicles have improved emissions efficiency. On the other hand, the intensity of PM10 has declined only marginally, implying limited progress.

Figure 2. Passenger cars : emission intensities (2018–2023)

Sub-question 2

In the figure below, we present the combined impact of Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs). These three categories represent the core of the new generation of low-emission and zero-emission vehicles. By grouping them together, we aim to capture the overall contribution of this technological transition within the automotive sector.

Since precise data on the emissions and energy consumption of each vehicle type are not yet available or vary significantly depending on usage patterns and regional factors, we assume that their environmental contributions are approximately equal. This assumption allows us to evaluate the collective effect of these advanced vehicle technologies on reducing total emissions and promoting cleaner mobility.

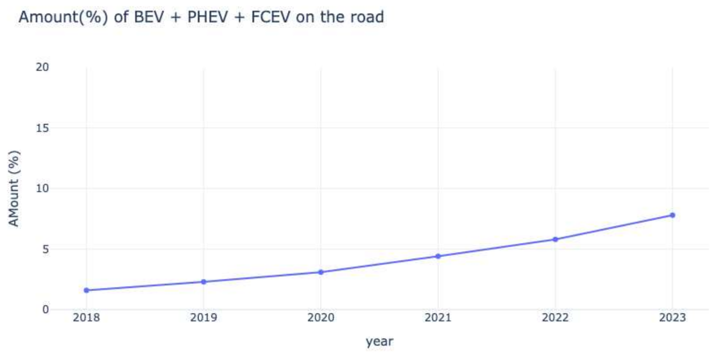

Figure 3: Combined share of BEV, PHEV, and FCEV in the Netherlands (2018–2023)

Sub-question 3

Between 2018 and 2023, the share of electric vehicles (BEV, PHEV, and FCEV) in the Dutch passenger-car fleet increased steadily from 1.5% to 7.0%. Over the same period, emission intensities for all measured pollutants CO_2, NOx, and PM_{10} showed a consistent downward trend, as illustrated in figures 4–6. The calculated correlation coefficients confirm a very strong negative relationship between EV share and emission intensity: r = –0.996 for CO_2, r = –0.922 for NOx, and r = –0.836 for PM_{10}. This implies that as electric vehicle adoption rose, emissions per kilometre driven decreased across all pollutants.

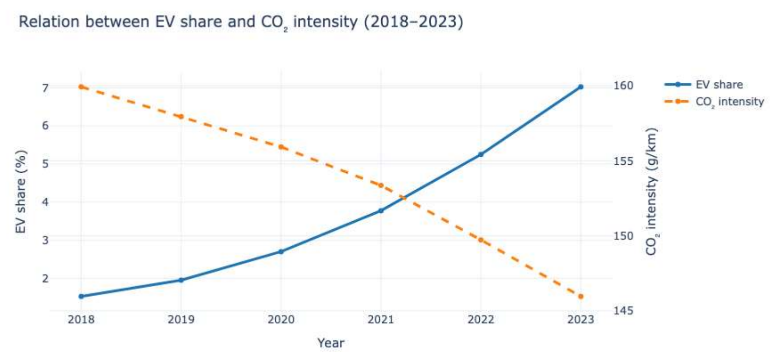

Figure 4: Relation between EV share and CO_2 intensity (2018–2023)

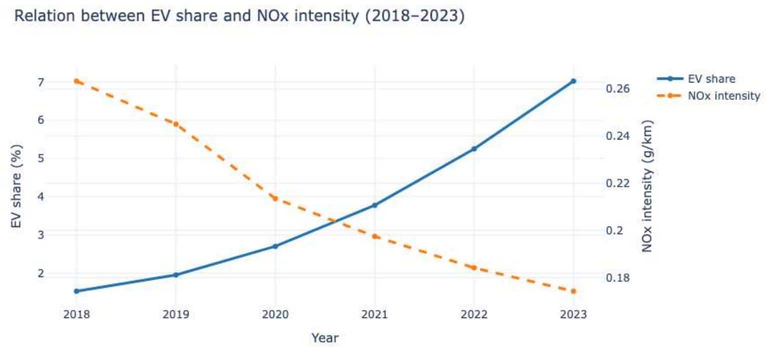

Figure 5: Relation between EV share and NO_x intensity (2018–2023)

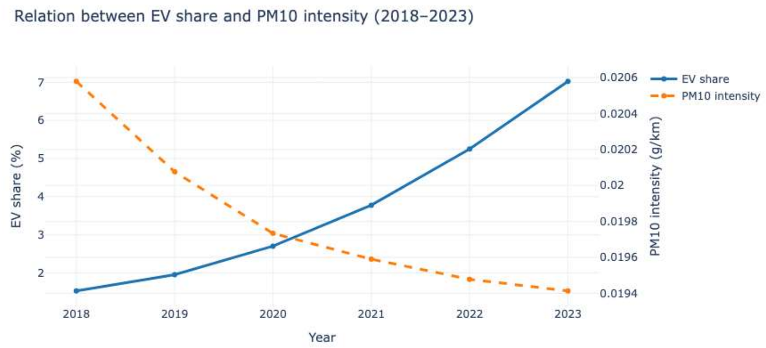

Figure 6: Relation between EV share and PM_{10} intensity (2018–2023)

The strongest correlation was found for CO_2, which directly reflects the replacement of internal combustion engine vehicles with zero tailpipe-emission electric vehicles. NOx intensity also decreased significantly, consistent with the reduction in exhaust-related pollutants from declining petrol and diesel use. PM_{10} intensity showed a slightly weaker correlation because non-exhaust sources, such as tyre and brake wear, are still present in both electric and conventional vehicles.

Table 2: Development of EV ownership and emission intensities for passenger cars in the Netherlands (2018–2023).
Source: CBS (2025), own processing.

Year	BEV (%)	PHEV (%)	FCEV (%)	Total EV share (%)	CO_2 (g/km)	NO_x (g/km)	PM_{10} (g/km)
2018	0.375	1.15	0.0	1.525	159.936	0.26331	0.02058
2019	0.85	1.10	0.0	1.95	157.948	0.24503	0.02008
2020	1.575	1.125	0.0	2.70	155.926	0.21347	0.01973
2021	2.35	1.425	0.0	3.775	153.358	0.19745	0.01959
2022	3.325	1.925	0.0	5.25	149.728	0.18406	0.01948
2023	4.425	2.60	0.0	7.025	145.954	0.17416	0.01941

Table 3: Correlation between EV share and emission intensities for passenger cars in the Netherlands (2018–2023).
Source: own processing.

Pollutant	Correlation Coefficient (r)	Relationship
CO_2	−0.996	Very strong negative correlation
NO_x	−0.922	Strong negative correlation
PM_{10}	−0.836	Moderate to strong negative correlation

These results collectively suggest that the growing electrification of the passenger-car fleet has contributed substantially to improving the environmental efficiency of road transport in the Netherlands. While the total emissions dropped partly due to the COVID-19 lockdown in 2020, the continued decrease in emission intensity in the years following indicates a structural improvement driven by technological change rather than temporary behavioural effects

Sub-question 4

The projection shows a continued rise in the share of EVs within the Dutch passenger-car fleet, increasing from about 7% in 2023 to roughly 14% in 2030. Correspondingly, the CO_2 emission intensity of passenger cars is expected to decline from around 146 g/km in 2023 to approximately 135 g/km by 2030. This represents an additional 7–8% reduction in average CO_2 emissions per kilometre compared to 2023 levels.

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The observed historical trend (2018–2023) already demonstrated a strong inverse relationship between EV share and CO_2 intensity (r = −0.996). Extrapolating this pattern with a linear relation suggests that further electrification will continue to lower the carbon intensity of road transport, provided that the increase in EV share follows the projected growth rate.

However, even with this steady improvement, the projected 2030 intensity of around 130–135 g/km remains well above national and European emission targets. The EU's CO_2 performance standards for new passenger cars require an average of 95 g/km by 2021 and a 55% reduction by 2030, equivalent to roughly 43 g/km for new vehicles(Bron). The Dutch government's climate objectives are consistent with these targets, aiming for a largely zero-emission new-car fleet by 2030.

Therefore, the projected trend based on historical growth, while positive, is insufficient to meet 2030 climate targets unless the transition accelerates substantially. Achieving the required emission intensity reduction will likely demand:

A much faster increase in EV market share beyond 14% of the fleet (toward 40–50% of new sales). Continued decarbonization of electricity generation to ensure that the life-cycle CO_2 benefits of EVs are fully realized. Policies targeting remaining internal-combustion vehicles through efficiency improvements and taxation incentives. In summary, the long-term growth in EV share is clearly driving down CO_2 emission intensity, but under current growth trajectories, the rate of improvement will not be sufficient to align with 2030 emission targets. A steeper electrification curve and broader systemic measures will be necessary to close the gap.

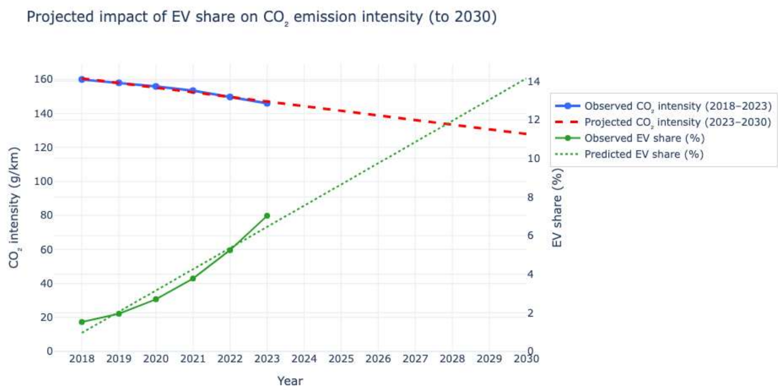

Figure 7: Projected impact of EV share on CO2 emission intensity (to 2023)

Conclusion

Between 2018 and 2023, the share of electric passenger cars (BEV, PHEV, and FCEV) in the Netherlands increased from around 1.5% to 7.0% of the total fleet. Over the same period, emission intensities for passenger cars declined across all measured pollutants: CO_2 decreased from 160 to 146 g/km, NOx from 0.26 to 0.17 g/km, and PM_{10} from 0.0206 to 0.0194 g/km. The correlation between EV share and emission intensity was strongly negative for all pollutants, indicating that higher levels of electrification are closely associated with lower emissions per kilometre. The increasing share of EV's has had the most effect on CO_2 and NOx , while PM_{10} reductions remained smaller because a significant portion originates from tyre and brake wear, which affects both electric and conventional vehicles.

A projection to 2030 indicates that if current growth continues, the fleet's CO_2 intensity could fall further to about 130–135 g/km. Although this represents meaningful progress, it remains above the EU target of roughly 43 g/km for new vehicles by 2030. Meeting these targets will require a faster transition to fully electric mobility, broader decarbonization of electricity generation, and the gradual phase-out of internal combustion engine vehicles.

Overall, the findings show that the electrification of the Dutch passenger-car fleet has already had a clear and measurable impact on reducing emission intensities, but a stronger acceleration in EV adoption will be essential to align future performance with national and European climate goals.

Discussion

During this project, several assumptions were made to ensure that the available data could be meaningfully applied to our research. Currently, we use data representing the total number of electric vehicles (EVs) in the Dutch vehicle fleet. However, this figure does not perfectly reflect the number of vehicles actively driving on Dutch roads. A more precise approach would involve using ownership or registration data to better represent the actual presence and use of EVs in daily traffic.

The selected emission indicators (CO_2, NOx, and PM_{10}) were chosen primarily because reliable public data were available for these pollutants. While they are relevant indicators for air quality and climate impact, they may not fully capture the emissions directly attributable to passenger cars. Future studies could investigate in more detail how strongly these emissions are linked to vehicle use and technology, or whether additional emission factors should be included for a more accurate representation.

Another important limitation concerns the aggregation of different types of electric vehicles. In this study, Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Fuel Cell Electric Vehicles (FCEVs) were grouped together as "electric vehicles." While this provides a clear overview of the general electrification trend, it overlooks the differences in emission behaviour between these types. BEVs make up the majority of the group and are fully zero-emission at the tailpipe, whereas PHEVs still rely partly on fossil fuels. Future analyses should therefore separate these categories to better understand the individual contribution of each technology to emission reductions.

Lastly, the projection towards 2030 was based on the least-squares method. Although this technique provides a sound statistical estimate of past linear trends, it does not account for potential exponential growth or decline in EV adoption. In reality, EV uptake is expected to increase more rapidly than predicted by the linear model, driven by technological progress, cost reductions in battery production, and new policy incentives. Moreover, several upcoming policy measures—such as stricter European emission standards and national subsidy programs—are likely to accelerate this transition. As such, the model's projections may underestimate the actual pace of change and future emission reductions.

In summary, while this study successfully identifies strong correlations between EV growth and declining emission intensities, several aspects could be improved in future research. Broader datasets covering more years, better differentiation between vehicle types, and more advanced modelling approaches would allow for a more accurate and nuanced understanding of the ongoing electrification of passenger transport in the Netherlands.

Data used

- CBS Data: Air emissions from road transport in the Netherlands -https://opendata.cbs.nl/#/CBS/nl/dataset/85347NED/table?ts=1760339509512
- CBS Data: Total vehicle kilometres in the Netherlands -https://opendata.cbs.nl/#/CBS/nl/dataset/83077NED/table?ts=1760339030369
- Duurzame mobiliteit databank: Share of BEV, FCEV and PHEV passenger cars in het vehicle fleet. - https://duurzamemobiliteit.databank.nl/mosaic/nl-nl/elektrisch-vervoer/personenauto-s

Contribution statement

At the start of the project, we proposed a research study on flight data, aiming to investigate how the war in Ukraine affected the frequency and routes of flights. Each person worked on collecting and processing the dataset, unfortunately the data turned out to be inaccessible. Therefore, we decided to develop a new research proposal.

Ties Timmerman: contributed to identifying the dataset and formulating the research objective. He worked on sub-question 2 and 3 and was responsible for integrating all code into the main Python file.

Twan Guleij: contributed to identifying the dataset and formulating the research objective. He wrote the introduction, worked on sub-question 2 and 4, and prepared the README file and wrote the conclusion.

Gijs Bezemer: contributed to identifying the dataset and formulating the research objective. He worked on sub-question 2 and 4 and wrote the discussion section.

Machtelt Boogers: contributed to identifying the dataset and formulating the research objective. She wrote the introduction, worked on sub-question 1 and 4, and made the Python text file lay out.

Emma ten Koppel: contributed to identifying the dataset and formulating the research objective. She wrote the introduction and worked on sub-question 1, 3, and 4.

AI statement

Parts of this report were supported by the use of OpenAI's ChatGPT to assist with data analysis, Python scripting, visualization, and the formulation of written explanations. The AI tool was used exclusively for computational support and language refinement; all data sources, analytical choices, and interpretations were made by the author. The AI tool was used to suggest and refine regular expressions in the "re" package, improve code readability, and provide guidance on certain Plotly visualization commands. The generated bits of code and text were reviewed, verified, and edited to ensure accuracy, validity, and compliance with academic standards and our data.

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- Tamba, M., Krause, J., Weitzel, M., Ioan, R., Duboz, L., Grosso, M., & Vandyck, T. (2022). Economy-wide impacts of road transport electrification in the EU. Technological Forecasting And Social Change, 182, 121803. https://doi.org/10.1016/j.techfore.2022.121803