Electric passenger vehicles reduce non-exhaust PM emissions

Robin Smit

1. INTRODUCTION

Battery electric vehicles (BEVs) have many benefits over their fossil-fuelled counterparts (internal combustion engine vehicles, ICEVs) in terms of greenhouse gas emissions and local air pollutant (exhaust) emissions. The only air pollutants that all on-road vehicles produce, including BEVs, are non-exhaust PM emissions due to brake wear, tyre wear, road wear and resuspended road dust.

Non-exhaust (NE) PM emissions are important. They generally dominate total PM (mass) emissions from road traffic. TER used the Australian Fleet Model (AFM) and COPERT Australia to estimate that non-exhaust PM contributes 70-80 percent to total PM emissions (mass) nationally for the Australian on-road fleet in 2020.

At a local scale there is, however, a lot of variability in these contributions. Nevertheless, even at a local scale, various research studies show that NE PM emissions are generally at least as important as vehicle exhaust PM emissions.

The extent to which increasing penetration of BEVs into the on-road fleet will have an impact on total NE PM emissions contributions is unclear and subject to debate. This study has therefore conducted a comprehensive review of the scientific literature and examined the main points of contention regarding non-exhaust PM emissions from BEVs. A probabilistic assessment was also conducted to quantify the expected impact of BEVs on non-exhaust PM emission levels. For full details and references, the report can be downloaded from: https://www.transport-e-research.com/publications.

Keywords: PM, Non-exhaust emissions, Uncertainty, Electric vehicles.

2. THE MAIN POINTS OF CONTENTION

***Point of contention 1**: BEVs are heavier than ICEVs, and therefore generate more non-exhaust PM emissions.*

There is consensus that heavier vehicles create more non-exhaust PM emissions. However, analysis of vehicle sales data shows that BEVs and petrol ICEVs have a similar average weight in countries with a relatively large and heavy passenger fleet, like Australia (TER, 2019). Moreover, data analysis shows that diesel ICEVs are 25-30 percent heavier than BEVs. This aligns with the 'SUV boom' that is observed around the world. This trend of buying heavier and more powerful passenger vehicles (PVs) is particularly strong for diesel PVs. The discussion of the impact of vehicle weight on NE PM is therefore incorrectly focussed on BEVs and should instead be focussed on diesel cars and SUVs.

***Point of contention 2**: BEVs use regenerative braking, which reduces non-exhaust PM emissions.*

Although this is in principle correct, the actual use of regenerative braking on the road is uncertain. The positive impact of regenerative braking on NE PM emissions and the real-world reduction in brake wear emissions are therefore also uncertain (reportedly ranging from 25 percent to 95 percent).

***Point of contention 3**: BEV driving behaviour is the same as ICEV driving behaviour.*

Driving behaviour is a major factor for non-exhaust PM emissions. Research studies that assess NE PM impacts incorrectly assume that driving behaviour does not change when people swap an ICEV for a BEV. However, other research has shown that BEV drivers may change routes to optimise for energy use and will likely exhibit a smoother (energy-saving driving) driving style, which will reduce non-exhaust PM emissions.

***Point of contention 4**: Resuspended road dust emissions are the same for BEVs and ICEVs.*

No data or information was found to suggest otherwise, although this does not mean there are no differences. The main issue in assessing this is the large local variability in resuspended road dust emissions and the risk of double counting wear emissions. Quantifying the relative impact of BEVs on resuspended road dust is therefore highly speculative. Given that diesel PVs are generally heavier than BEVs in Australia, it seems likely that diesel cars and SUVs will create more resuspended dust than BEVs.

***Point of contention 5**: Atmospheric chemistry is not considered.*

PM concentrations are not only the result of direct PM emissions from vehicle exhausts and wear (primary aerosols), but also the result of particles subsequently formed in the atmosphere (secondary aerosols).

Secondary PM may significantly contribute to total PM concentration levels with reported values between 25 percent and 50 percent of ambient PM concentration levels. Often this aspect is not considered in the reviewed research studies because dynamic and complex chemistry processes in the atmosphere complicate the assessment of impacts of secondary PM. Data presented in recent studies (e.g. Chan *et al.*, 2019; Broome *et al.*, 2020) suggest that even in countries where BEVs are largely powered by coal-fired power stations (e.g. Australia), electrification of the on-road fleet will improve urban air quality with respect to total ambient PM concentrations (primary and secondary combined), as compared with the current almost 100 percent fossil-fuelled on-road fleet.

3. PROBABILISTIC ASSESSMENT

The previous section demonstrates the complexity in properly assessing the impact of BEVs on non-exhaust PM emissions. It shows that the conclusions from international research studies are often based on various (often debatable) assumptions leading to uncertainty and contention. Moreover, given differences in, for instance, fleet composition, it is not valid to translate the results of these international studies directly to the local situation.

A probabilistic assessment was conducted to quantify the expected impact of BEVs on NE PM emissions. This approach explicitly considers the variability and uncertainty in NE PM emissions, which is important in the light of limited empirical data. Emission factor distributions were created by extracting mean emission factors from the available literature (Figure 1).

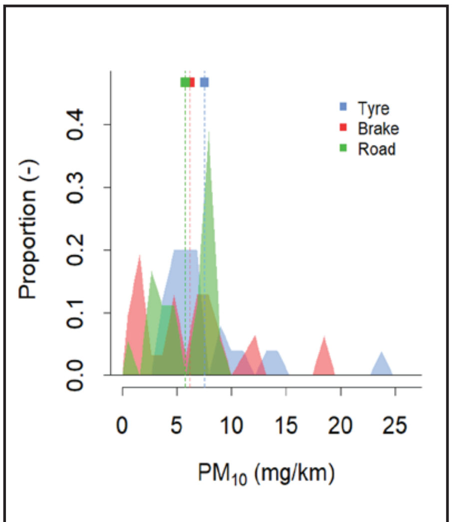

Figure 1. Mean non-exhaust PM_{10} emission factor distributions (paved roads) from international literature, bootstrap grand mean values are shown as squares at the top of the charts

A bootstrap simulation was conducted to estimate the grand mean and associated non-symmetric 95 percent confidence intervals (95% CI) for each non-exhaust PM source. The results are shown in Table 1.

Non-Exhaust PM Aspect	$PM_{2.5}$ (mg/km)	PM_{10} (mg/km)
Tyre Wear	3.1 (1.8 – 4.5, n = 10)	7.6 (6.1 – 9.3, n = 25)
Brake Wear	2.4 (1.6 – 3.1, n = 15)	6.2 (4.7 – 7.9, n = 31)
Road Wear	3.6 (2.6 – 4.1, n = 6)	5.8 (4.7 – 6.8, n = 18)
Resuspension	7.2 (3.8 – 11.4, n = 13)	94.4 (37.5 – 175.6, n = 22)

Table 1. Mean Non-exhaust PM emission factors for ICEVs (Bootstrap 95% CI, n = sample size)

The NE PM emission factors for both ICEVs and BEVs were computed with two linear models. A Monte Carlo simulation was used to propagate the uncertainty in the input distributions to the model outputs. TER analysis estimates that a 100 percent Australian on-road BEV fleet will reduce both NE $PM_{2.5}$ and PM_{10} emissions with 95% CI. BEVs are expected to reduce fleet average $PM_{2.5}$ NE emission rates somewhere between 1 percent to 34 percent (on average 11 percent and reduce PM_{10} NE emission rates somewhere between 1 percent to 46 percent (on average 13 percent).

4. CONCLUSIONS

The weight of evidence suggests that statements that BEVs will not improve or even increase non-exhaust PM emissions are incorrect for countries with heavy passenger vehicle fleets like Australia.

In a time where a move to zero emission transport is urgently required to meet international and local greenhouse gas emission targets, non-exhaust PM emissions should not be used as an (invalid) argument against rapid electrification of the on-road fleet. This study suggests that instead the focus should be on reducing the sale of (heavy) diesel PVs, which are expected to be a more important source of non-exhaust PM emissions.

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AUTHOR

Robin Smit
Transport Energy/Emission Research (TER), Brisbane, Australia