Transportation Research Part A 135 (2020) 358–360

Contents lists available at ScienceDirect

Transportation Research Part A

journal homepage: www.elsevier.com/locate/tra

Who will bell the cat? On the environmental and sustainability risks of electric vehicles: A rejoinder

Francisco Bahamonde-Birke

Sociale Geografie en Planologie, Universiteit Utrecht, the Netherlands

1. Introduction

I am frankly surprised by the arguments raised by Lasse Fridstrøm in his comment on my research note on the environmental and sustainability risks of electric vehicles. The reason for my surprise is that the large majority of the points contained in his extensive plea for electric vehicles (EV) have absolutely nothing to do with the arguments contained in the research note on the environmental risks of EVs. It seems as if instead of rebutting the propositions contained in the note, he centered his arguments on rebutting evidently false premises by standing up a series of straw men, which I have obviously not argued for.

Just to summarize, the main point I made in my comment is that EVs are not a panacea and have no superior environmental performance *per se* than internal combustion engine vehicles (ICEV). Whether their environmental performance is superior or inferior depends on the way the energy used by EVs is generated. Moreover, I aimed at stressing the differences between marginal and average emissions. During the last years, in many studies, EVs are associated with the average emissions of the grid (or even with zero emissions; more on that below). This approach, while widely-extended (especially among politicians and practitioners, but also among academics) is not appropriate to reflect the actual impact of EVs. If new EVs enter the road, the average emissions of the grid are no longer relevant, as they reflect the average of the energy currently being consumed. The analysis should be focused on the extra energy that needs to be generated for the new EVs (which in economics is called the marginal approach). In this particular case, the difference between the average emissions approach and the marginal emissions approach (or equivalently, a full-emissions approach) is highly important, as renewable sources (which substantially lower the average) are mostly no longer available when EVs are being charged. Hence, having more EVs on the road, normally implies that more energy has to be generated using fossil energy (which has substantially larger emissions than the average) and, consequentially, the increase in total emissions associated with charging EVs is considerably larger than associating them with the average emissions of the grid (Hawkes, 2014). Note, however, that the former goes both ways: if EVs are charged when there is a surplus of renewable sources (e.g. EVs being charged during a windy, sunny summer day), EVs would have no impact on the emissions whatsoever. However, the empirical evidence shows that without appropriate incentives EVs are mostly being charged during evening hours (Anderson et al., 2018), when, in many countries, the entire marginal generation comes from coal or lignite.

The comment by Fridstrøm begins by standing up a straw man by implying I would claim that Diesel engines would be efficient from an energetic viewpoint and extensively discusses the superior efficiency of electric engines. Of course, electric engines have a superior energy efficiency, but that is not the point at all. I merely claim that within ICEVs, Diesel or LPG vehicles have a superior performance in terms of CO_2 emissions/km (compared with gasoline vehicles). Furthermore, whether the CO_2 efficiency of electric vehicles is superior or not does not (only) depend on the energetic efficiency of the motor, but on the CO_2 emissions associated with the generation/transmission/storage of electricity. Finally, Fridstrøm finishes his claim by highlighting the enormous importance of ICEV on the global CO_2 emissions, which is again an unquestionable truth. However, the question is not that, but whether blindly replacing ICEVs by EVs (i.e. not paying attention to their actual impact on the electric grids) would contribute to reducing this impact or not.

The second point raised by Fridstrøm (again a straw man) is that in the USA, on average, the CO_2 footprint of EVs is smaller than

E-mail addresses: bahamondebirke@gmail.com, f.j.bahamondebirke@uu.nl.

https://doi.org/10.1016/j.tra.2020.03.018

Available online 20 March 2020

those of ICEVs. However, I fail to see how this relates to the argument that CO_2 emissions relate to the marginal emissions of the grid. Moreover, even the source referenced by Fridstrøm claims: "*Based on a calculation of regionalized marginal emission factors of electricity, we find that under relatively low carbon intensity electricity conditions, such as the Western Electricity Coordinating Council (WECC) with daytime charging, emissions from today's BEVs are reduced by about 50% compared to ICEVs and by about 25% compared to HEVs. In regions with high carbon intensities of electricity, for example the Midwest Reliability Organization (MRO) with nighttime charging, BEVs do not outperform (P)HEVs, and they emit only about 25% less than comparable ICEVs*" (Mioti et al., 2016[1]). This does not only not support the claim of absolute superiority of EVs, but also sustains the importance of the grid's marginal emissions during the charging period. Furthermore, in the USA, ICEVs are almost exclusively gasoline vehicles (TecAlliance, 2018), which exhibit a poorer environmental performance (in terms of CO_2 emissions) than Diesel or LPG vehicles. Note also that the networks in the USA are less carbon-intensive (in terms of marginal emissions), due to the extensive use of gas, than networks (like in many Europeans countries) in which marginal emissions arise from coal and lignite (Siler-Evans et al., 2012; Reget et al., 2018; Schram et al., 2019).

Then, in the following three headlines, Fridstrøm raises a valid point (actually, the only one that refers to the original research note), when he addresses the impact of EVs in the context of cap-and-trade systems like the European Union's Emissions Trading System (EU-ETS). As correctly discussed by Fridstrøm, in the context of the EU-ETS the total CO_2 emissions of the electric network are hard-capped, meaning that every kilometer driven with EVs does not result in more CO_2 emissions (it would result in a transfer of CO_2 emissions permits and larger energy prices, but no larger emissions). However, it is absolutely incorrect to claim that EVs would be superior to ICEVs *per se* because of existence of the regulation; if anything, what we are capturing is the effect of imperfect regulation, which regulates the emissions of EVs, but does not (perfectly) regulate the emissions associated with ICEVs[2]. For instance, if a given country would decide to compensate all CO_2 emissions associated with lignite power plants (the less efficient technology in terms of emissions/energy), one could argue that in this specific country this technology (lignite) exhibits a better ecological performance than alternative sources such a renewable energy, gas, diesel, or coal. This is, however, incorrect, as it is not the technology the cause of the better ecological performance, but the regulation. The country would achieve better results by promoting and using the same amount of money to compensate the emissions of alternative (more efficient) technologies. Hence, relevant questions, in order to assess different technologies would be:

– Provided no technology is subject to the regulation, what would be the most effective technology?

This case would represent a laissez-faire scenario and it is straightforward to see that the technology with the lesser marginal CO_2 emissions (opportunity costs aside) is the more environmentally friendly alternative (in terms of CO_2 emissions).

– Provided all technologies are subject to the same regulation, what would be the most effective technology?

If all different power trains would be covered EU-ETS, it is also straightforward to see that the technology with the lesser marginal CO_2 emissions should be preferred, as it would result in less and cheaper CO_2 permits, putting much less pressure on the system.

– Is it possible (technically, socially, economically, etc.) to apply the same regulation to all technologies?

Yes. It is absolutely possible to impose mandatory CO_2 compensation to ICEVs. Actually, currently in many European countries gas stations offer the possibility of compensating CO_2 emissions on voluntary base, while some countries (e.g. Germany or France) are considering mandatory CO_2 emissions compensation for ICEVs (note that if this regulation is enacted the entire argument about EVs being environmentally friendlier because of regulation would become a moot-point).

It is important to note that if all technologies are subject to mandatory CO_2 emissions compensation, all technologies would be effectively carbon-neutral (making no difference between EVs and ICEVs). The only difference would be given by the amount of CO_2 emissions permits that needs to be acquired per kilometer (which would be less for technologies with lesser marginal CO_2 emissions). This difference is not minor at all, since, as pointed by Fridstrøm, ICEVs represent a large percentage of the total CO_2 emissions in the area covered by the EU-ETS. If all vehicles would have to compensate their CO_2 emissions (be it because all ICEVs are replaced by EVs or because all ICEVs are included into the EU-ETS) the price of CO_2 emissions permit would drastically increase (Hintermann, 2017), putting a lot a pressure on the system. Under these circumstances, it becomes obvious that the technology requiring the lesser amount of emissions permits (which is the one with the lesser marginal emissions) should be preferred.

Along these lines, Fridstrøm claims that an advantage of EVs is that every person switching from ICEVs to EVs effectively moves its vehicle under the cap, which creates an environmental incentive to do so. However, the environmental benefit does not differ from the benefits achieved when individuals voluntarily pay for the compensation of CO_2 emissions of ICEVs (although, the price and, consequentially, the pressure imposed on the EU-ETS would be less for the technology with the lesser marginal emissions). I deliberately refrained from proposing a way to include ICEV into the EU-ETS, as it largely escapes the scope of the research note.

[1] References to figures have been deleted in the citation.

[2] Note that the CO_2-emissions of ICEVs are somehow regulated by fuel-taxes. However, as fuel taxes, are not directly linked to CO_2-emissions, neither in their collection, nor in the way the money is spent, this regulation is widely imperfect. Anyway, given that, at least, a certain amount of the fuel taxes is used in CO_2 emissions abatement, the claim by Fridstrøm that "*CO_2 emissions are therefore reduced by the full amount of gasoline and diesel combustion avoided when an ICE vehicle is replaced by a BEV*" is plainly wrong and cannot be sustained from an economic point of view.

However, I would argue that leaving the decision of whether to move emissions under the EU-ETS cap should not be left to users switching from ICEVs to EVs or paying voluntarily for CO_2 emissions compensation, but it should be politically/technically/ economically steered by the regulatory authority.

Finally, Fridstrøm starts a long discussion on a series of topics that have absolutely nothing to do with the research note, like the difficulties that the electric networks of many countries will face to accommodate the increased electric demand for EVs, the barriers to EVs at the consumer's level, the requirement of subsidies or the ineffectiveness of shutting down nuclear power plants without an adequate way to store the volatile renewable sources (which have resulted in increased dependence on fossil sources). I agree with most of these points, but I frankly fail to see how anything of this (as well as the points raised earlier) can be understood as a criticism to the statement that EVs are not *per se* environmentally superior to ICEV and that the environmental performance depends on their marginal emissions of the grid. However, by making these points Fridstrøm provides an excellent opportunity to illustrate the differences between countries and electric grids and why, in many places, a switch from ICEVs to EVs should not be blindly incentivized: when discussing the barriers to electrification Fridstrøm claims that the "*likelihood of opting for an electric vehicle increases substantially if the owner is able to recharge the car at home*". Being able to recharge the vehicle at home indeed increases the appeal of EVs, but at the same encourages that the vehicle be charged precisely when the marginal emissions of the grid are the largest (namely during the evening). Hence, while improving the possibilities to charge the vehicle at home would increase the demand for EVs, at the same it would worsen their environmental performance. Obviously, being based in Norway (where the electric mix is almost completely based on hydropower), these aspects are of secondary importance to Fridstrøm, but they cannot be left aside in the majority of the countries. Along these lines, it is important to note that promoting EVs via subsidies (including tax exemptions, which are basically a negative reinforcement) necessarily implies (i) that public resources that could have been otherwise used to promote non-motorized and public transportation are being deviated to promote private transportation, and (ii) that additional demand for private transportation is being induced.

Fridstrøm summarizes his comment by claiming that "*there is nothing wrong with the climate and environmental characteristics of electric vehicles per se*". I fully agree, but I need to add that there is also nothing that is *per se* right with them (which is the core of the research note and it obviously does not contradict Fridstrøm's claim). The goal is not EVs for the sake of EVs. The goal is improving the sustainability of transportation systems and if EVs contribute to this goal, then it is a step forward. However, EVs do not contribute to the latter goal if their marginal CO_2 emissions are larger than the marginal CO_2 emissions of ICEVs[3] (and they contribute even less if they are promoted using resources that could have been used to improve non-motorized and public transport otherwise). There are many countries where the electric grids allow for EVs to be almost carbon-neutral (e.g. Norway, Iceland, Costa Rica, etc.). In several other electric networks EVs are superior to ICEVs, but also, in carbon-intensive grids (in terms of the marginal emissions) EVs may be associated with larger CO_2 emissions than ICEVs.

It is also important to note that marginal emissions vary throughout the day (given the volatility of renewable sources), and consequentially EVs charged during electric surpluses (especially during daytime in the summer months) have a considerable superior performance to ICEVs and EVs charged during the evening hours. But taking advantage of this potential requires adequate incentives at consumer's level, which necessarily includes changes in the price structure (certainly not flat electric prices for the end-consumers, as it is the case in most countries). It also would require the development of an extensive bidirectional charging network, so that EVs could be charged during surpluses and deliver energy back to the grid during shortages (which would necessarily need to take into account the spatial characteristics of transportation demand, to avoid that EVs kept being charged during the evenings at home, when the marginal emissions are the largest). But above all, it would require a change in the way EVs are seen and used by the population. However, these changes are not likely to happen, unless researchers, practitioners, politicians and the general public recognize that EVs are not a panacea, that the when and how EVs are charged matters, that associating EVs with the average emissions of the grid widely underestimates their footprint, that having a different regulation does not make a given technology cleaner (provided the same regulation can indeed be applied, which is the case for EV/ICEV), that a similar regulation on CO_2 emissions should apply to both EVs and ICEVs, that a large-scale introduction of EVs for the sake of introducing EVs (as targeted by many European countries with carbon-intensive grids) does not necessarily contribute to sustainability (especially in those countries), that deviating funds from subsidies for public transport and active transportation modes to subsidies for EVs is counterproductive, that selling (everywhere) the image of green EVs and dirty ICEVs is misleading; in summary, recognizing that the goal is sustainability and not EVs. I am positive I am belling the right cat.

References

Anderson, J.E., Steck, F., Kuhnimhof, T., 2018. Can renewable energy sources meet electric vehicle charging demand today and in the future? A microscopic time-specific travel demand analysis for Germany. Transportation Research Board 97th Annual Meeting, 7–11. January 2018, Washington, D.C., USA.

Miotti, M., Supran, G.J., Kim, E.J., Trancik, J.E., 2016. Personal vehicles evaluated against climate change mitigation targets. Environ. Sci. Technol. 50 (20), 10795–10804.

Siler-Evans, K., Azevedo, I.L., Morgan, M.G., 2012. Marginal emissions factors for the US electricity system. Environ. Sci. Technol. 46 (9), 4742–4748.

Hawkes, A.D., 2014. Long-run marginal CO_2 emissions factors in national electricity systems. Appl. Energy 125, 197–205.

Regett, A., Baing, F., Conrad, J., 2018. Emission assessment of electricity: Mix vs. Marginal power plant method. In: 2018 15th International Conference on the European Energy Market (EEM) (pp. 1-5). IEEE.

Schram, W., Lampropoulos, I., AlSkaif, T., & Van Sark, W. (2019). On the use of average versus marginal emission factors. In: SMARTGREENS 2019-Proceedings of the 8th International Conference on Smart Cities and Green ICT Systems, SciTePress, pp. 187–193.

Hintermann, B., 2017. Market power in emission permit markets: theory and evidence from the EU ETS. Environ. Resour. Econ. 66 (1), 89–112.

TecAlliance, 2018. Automotive Report 2018.

[3] Note that this also holds if EVs and ICEVs are subject to the same regulation.