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Commentary

Can electric vehicles deliver sustainable mobility in low-income countries?

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Introduction

Globally, transport is responsible for around a quarter of anthropogenic greenhouse gas (GHG) emissions. It is often the largest emitting end-use sector in the high-income countries (e.g., UK, US) but exhibits the slowest rate of reduction. Demand for transport activity and associated emissions continue to grow, especially in low- and middle-income countries. Decarbonizing transport is difficult due to its very heavy reliance on fossil fuels, strong links to economic development, convenience of motor vehicles as a transport mode, and the sheer volume of vehicles in operation (over 1 billion cars) that need to be decarbonized. Electrification has emerged as the key strategy to mitigate GHG emissions—especially for light-duty passenger vehicles—leading to a global increase in electric vehicle (EV) sales in the past few years. Significant international funding is being directed toward low-income countries to facilitate the transition to EVs, while a low-income country—Ethiopia—recently became the first to ban the import of internal combustion engine (ICE) cars to encourage EVs.

However, given the lessons of unforeseen consequences of new technologies—the diesel emissions debacle in Europe is a prime example—it is important to assess EV's sustainability credentials further. There is a large body of literature on different sustainability aspects of EVs individually: e.g., GHG performance,[1] potential for reducing criteria air pollutants and improving public health,[2] financial sustainability,[3] and environmental and social impacts of resource consumption for EV batteries.[4] This literature primarily uses cars or vehicles as the lens to analyze EV's impacts. On the other hand, private cars are only one component of the larger mobility system, and transport policy makers are now interested in the overall sustainability of this system. This is wider than the vehicle-centric approach to EV sustainability or life cycle emissions and have different goals and indicators. There is little research on EVs' role in the context of achieving sustainable mobility—not only in low-income countries but also in middle- or high-income nations. Here, we discuss the potential for EVs in achieving (or not) the goals of sustainable mobility in low-income countries, using examples from Asia and Africa.

Low-income countries are particularly important in the context of electrification and sustainable mobility. The objectives of sustainable mobility in these countries can be different from those in high-income countries given their vastly different transport system, economic and development status, and future priorities. The passenger vehicle type distributions are also very different, for example, motorcycles constitute a very important vehicle segment in low-income countries (e.g., in Bangladesh and Kenya, motorcycle population is five and two times that of private cars). Electrification in some low-income countries like Bangladesh and Tanzania is also occurring in three-wheeler paratransit-type vehicles, with potentially very different implications from electrifying cars, as is happening in the high-income countries.

There are a number of sustainable mobility frameworks mentioned in literature: World Bank's Sustainable Mobility for All[5] uses four broad goals (six with sub-goals), but we use the seven goals of sustainable mobility by the World Business Council on Sustainable Development[6]—these goals provide a crisp description of the targets for sustainable mobility, are not dependent on a plethora of data-intensive indicators, and are more conducive to a qualitative commentary, as we describe below.

Goal 1: Reduce conventional emissions from transport so that they do not constitute a significant public health concern anywhere in the world

Large and mega cities in the low-income countries consistently experience very high levels of local air pollution, which is responsible for various adverse health outcome (e.g., asthma and similar respiratory illness) including premature deaths. Air pollution in these cities is exacerbated by exhaust emissions from a growing ICE vehicle (ICEV) fleet, old and polluting ICEVs, idling due to congestion, weak or few emission regulations, and poor monitoring and enforcement. As such, around 74,000 premature deaths could be attributed to air pollution from the transport sector alone in India in 2015.[7] Unlike the ICEVs, EVs have zero tailpipe emissions of local air pollutants and—despite the potential for some increases in particulate emissions from tire frictions due to their heavier weights—EVs will substantially improve local air quality in cities and reduce risks to public health.[2] There are some risks of upstream air pollution during electricity production, but power plant emissions generally happen away from large population centers, with reduced risks to public health compared to tailpipe emissions from ICEVs in cities.

It is important to put these air quality benefits in the context of low-income countries, though. Vehicle fleet in low-income countries almost entirely consists of imported new or used vehicles from relatively few vehicle-manufacturing countries, which tend to have reasonable emission standards. Therefore, the vehicle stock in low-income countries is getting cleaner over time. Addressing the relatively small share of super-emitters—poorly maintained commercial diesel vehicles such as buses, minibuses, and trucks—via a strong inspection and maintenance program will likely improve air quality faster and farther, compared to converting the larger fleet of relatively clean private cars to EVs.

Motorcycles are likely a significant source of air pollution in low-income countries due to their less stringent emission standards, relaxed monitoring, large share in the vehicle stock, and intensive use as informal commercial passenger transport (especially in Southeast Asia and sub-Saharan Africa). Therefore, motorcycle electrification—being piloted in quite a few Asian and African countries—will likely bring more benefits early on compared to electrifying cars. It is encouraging that the three-wheeled autorickshaws and the highly polluting indigenous vehicles—powered by one-stroke shallow engines used for irrigation and locally known as Nosimon, Korimon, Votvoti—are being replaced by electric three-wheelers in Bangladesh (however, the health benefits may not be large as they used to operate primarily in less densely populated areas). Since there are around half a billion two- and three-wheelers in Asia and Africa, electrifying these will result in perceptible air quality and health benefits, especially in urban areas.

Of course, transport is not the only source of air pollution, and source apportionment studies suggest that less than one-fourth of local air pollution in Dhaka or Karachi arises from vehicle fuel combustion. As such, there are potentially other, more effective, and efficient means to improve local air quality in these places. Nonetheless, electrification of vehicles will reduce the transport share of local on-road emissions and improve public health further—substantially, if electrification of the high-emitting vehicles are prioritized carefully.

Goal 2: Limit greenhouse gas emissions from transport to sustainable levels

EVs are more energy efficient than similar ICEVs, but—despite the zero tailpipe emissions—their GHG mitigation potential directly depends on the upstream energy sources (fossil fuel vs. renewable sources) for electricity production. Especially the source of the additional electricity to power the EVs is crucial in this context. Electricity production in most countries is currently dominated by fossil fuels such as coal and natural gas, making the EVs relatively carbon intensive too. Bangladesh, Nigeria, and India have grid carbon intensities of 691 g/kWh, 523 g/kWh, and 713 g/kWh, respectively, while in the UK—a high-income country that is cleaning up its grid—it is 238 g/kWh.[8] Indian studies show that despite its relatively high average grid carbon intensity, EVs still reduce carbon emissions marginally (16%) over ICEVs during their life cycle,[9] although some states can show an opposite pattern.[1] Clearly, the carbon implications of electrifying the same vehicle in these countries will be very different, with a better return in the UK (65% reduction on a life cycle basis[10]) and similar countries with lower grid carbon intensity. In many low-income countries, the grid is expected to get more carbon intensive in the near future before they get cleaner in the long run, when capital-intensive renewable-energy-based generation may become mainstream. Therefore, EVs will likely reduce transport GHG emissions in most of these countries, but only modestly—at least in the next decade. Country-specific risks (e.g., some Central Asian countries have high grid carbon intensity) of increased GHG emissions due to vehicle electrification should not be underestimated, either.

On the other hand, in some sub-Saharan countries, the electricity production process is much less carbon intensive (e.g., Uganda 45 g/kWh, Kenya 70 g/kWh[8]) due to their high use of renewable sources. Electrifying vehicles in these countries will rapidly reduce GHG emissions from their transport sector, provided the additional electricity continues to come from a similar or cleaner mix of primary energy resources. From a purely efficiency perspective, vehicle electrification should be prioritized in such countries with low grid carbon intensity. Essentially, vehicle electrification decisions should be linked to grid decarbonization in order to reap the most benefits.

It is important to note that the 176 countries outside of the 19 G20 countries are collectively responsible for only 22% of global GHG emissions.[11] Transport is responsible for only 11%–13% of energy-related CO_2 emissions in India, Bangladesh, and South Africa.[12] While transport GHG emissions are growing in low-income countries, they are growing from a relatively small base. As such, the immediate GHG-driven need for electrifying vehicles in most low-income countries can be questioned against the more pressing challenge of providing access to reliable and affordable electricity for residential and industrial use or providing affordable, reliable, and equitable transport opportunities for the people (which is a goal of sustainable mobility, too).

Goal 3: Significantly reduce the number of transport-related deaths and injuries worldwide

Globally, around 1.19 million people get killed and another 20–50 million get injured in road accidents every year,[13] with disproportionately large impacts on vulnerable road users (VRUs) like pedestrians and motorcyclists. In low-income countries, more than 80% of traffic crash fatalities involve VRUs in contrast to a 50% VRU death rate globally. Vehicle electrification itself does not inherently provide additional safety benefits over ICEVs, except for the reduced fire risk for mainstream EVs (around a tenth of ICEVs). While electric cars currently in the market in high-income countries are often packed with superior safety features made possible due to their higher prices, similar safety measures can be incorporated into ICE cars too.

EVs can still significantly influence road safety dynamics. In collisions between two motor vehicles, EV occupants likely benefit from the vehicles' substantially heavier weight arising from the batteries. Yet, this extra weight increases risks to both VRUs and occupants in lighter vehicles. While reliable EV specific studies are yet to emerge, there is clear evidence that collision with a heavier vehicle increases fatality risks.[14] Therefore, EVs will likely increase the risks of severe injuries to VRUs and occupants in similar sized ICEVs.

The relatively quiet operation of EVs also poses increased risks to VRUs, especially in noisy urban areas and to those with visual impairments. While EVs now include artificial noise via the acoustic vehicle alert system (AVAS) to mitigate this risk, it will likely need recalibration in cities like Lagos or Dhaka due to their very noisy urban environment.

In some low- to middle-income countries, electrification primarily involves locally modified or assembled three-wheeled vehicles. These include the retrofitted electric rickshaws in Bangladesh, with 3–4 lead-acid batteries assisting pedal-based propulsion, and the more popular fully electrically propelled autorickshaws (easy bikes in Bangladesh and e-tuktuks in Tanzania and the Philippines), which have 6–8 lead-acid batteries, smaller wheels, more robust frames, higher speeds, and larger seating capacity. These vehicles often operate outside regulatory oversight and lack proper registration, fitness certification, or even driver licensing. Despite their unauthorized status, an estimated 1–4 million easy bikes operate in Bangladesh.[15] These vehicles have higher weights than their pedal or ICE counterparts, often coupled with inferior braking and lighting systems. This unregulated electrification substantially exacerbates the risks of road crashes, fatalities, and injuries. On the positive side, easy bikes appear to have replaced the small fleet of indigenous vehicles in rural areas in Bangladesh, which were even riskier. Countries such as Pakistan and Rwanda have sales targets, while Indonesia (a lower-middle-income country) offers purchase subsidies for electric two- and three-wheelers, but their safety impacts have not been studied.

Goal 4: Reduce transport-related noise

Electric motors are noticeably quieter than ICEs. This quiet operation, particularly evident at low speeds prevalent in large and mega cities in most low- and middle-income countries, has the potential to reduce road noise significantly. However, in bustling cities such as Cairo or Karachi, where indiscriminate honking and exhaust noise from poorly maintained vehicles are possibly major contributors to road noise, the beneficial effect of EVs on overall noise reduction will likely be limited. Moreover, urban noise pollution in these cities stems from various other non-transport sources (e.g., construction, public loudspeakers), further diminishing the potential impact of EVs on noise reduction.

On the other hand, ICE motorcycles, with their exposed engines and smaller exhaust and muffler systems, can be nearly twice as loud as ICE cars. While precise data are unavailable, given their dominant share in the vehicle fleet, motorcycles are likely a significant contributor to road noise pollution in the large cities in low- and middle-income countries. Especially, motorcycle engine noise during acceleration after traffic stops appears to be a major source of noise-related annoyance. Electrifying motorcycles, a trend gaining traction in middle-income countries such as India and China and being piloted in low-income countries such as Tanzania, Cambodia, and Uganda, will likely have a more pronounced effect on reducing road noise in mega cities compared to electrifying cars.

Goal 5: Mitigate traffic congestion

Megacities in the low- and middle-income countries—from Dhaka to Mumbai to Karachi to Lagos—are well known for their severe traffic congestions. With its large environmental, social, and economic repercussions, congestion poses a significant challenge in these cities. There are myriad reasons for traffic gridlock in these cities—rapidly rising vehicle ownership (along with slow expansion in

Table 1. Potential for achieving sustainable mobility goals by electrifying different types of vehicles

Sustainable mobility goal	Contribution to the goal by electrifying ... Cars	Buses	Three-wheelers	Motorcycles
Reduce local air pollution	+	++	+	++
Reduce GHG emissions	+	+	+	+
Improve road safety	≈	≈	– –	–
Reduce noise	+	++	++	++
Reduce congestion	≈	≈	+	≈
Narrow mobility divide	–	≈	+	≈
Improve mobility opportunities	≈	≈	+	≈

Red: less certain, context-dependent impact; black: higher likelihood of impact.

road infrastructure) and lack of alternate mass transport modes being the principal ones. Since EVs typically serve as direct replacements of ICEVs, it is highly unlikely that the simple replacement of ICEVs by EVs will reduce private vehicle usage and alleviate congestion. Instead, the lower operational costs of EVs compared to ICEVs may lead to increased driving distances, a phenomenon known as the rebound effect, and thus potentially aggravate congestion further. This is supported by earlier studies that show that the conversion of vehicles to run on compressed natural gas had reduced the per-mile running costs of vehicles and increased driving distances per converted car in Dhaka.[16] Early evidence on rebound effects of EVs in Germany alleviate this concern somewhat, though.[17]

Goals 6 and 7: Narrow mobility divides that exist within all countries and between the richest and poorest countries and improve mobility opportunities for the general population in developed and developing societies

Approximately 1 billion people worldwide, more than 30% of people in rural areas, lack access to good transport provisions.[5] Within a country, mobility disparities can stem from factors such as wealth, gender, race, religion, age, physical ability, or location. Disparity in access to transport services can occur in both low- and high-income countries and for electric mobility, too. Even in the high-income countries, high initial costs bar low-income households and communities from accessing the benefits of electric vehicles,[18] and the problem will be more acute in low-income countries for mainstream electric vehicles. Especially, most low-income countries depend on used ICEV imports, which is a large uncertainty for EVs given the consumer concern about battery life and costs of battery replacement and their as-yet-unknown effects on the international used-vehicle market for EVs. Importing new EVs instead of used ICEVs will make cars even less affordable. Unreliable supply of electricity is a major area of concern in low-income countries, too—especially in areas outside of major urban centers, potentially exacerbating an urban-rural divide.

Turning our focus to public transport, boarding a crowded electric bus is not any easier for the women or people with disabilities than boarding a crowded ICE bus. Strategies to bridge mobility gaps, e.g., public transport provisions or accessible design, are not necessarily enhanced by electrification and may even be hindered due to the steep upfront costs of EVs and related infrastructure, which will compete for the already limited resources in low-income countries. Similarly, mobility opportunities for the general population are not necessarily improved by electric cars or buses.

The electric three-wheelers can contribute positively toward both of these goals in low-income countries. At present, these electric three-wheelers mostly operate as paratransit and are cheaper to run than their ICE counterparts in Bangladesh, India, or Tanzania, with corresponding savings for passengers, too.[3] They operate in a gray regulatory regime and have become popular due to their favourable economics, with little government support. The easy bikes in Bangladesh have mostly replaced the small fleet of indigenous shallow-engine vehicles to improve the mobility offerings in rural areas and small towns and helped reduce the mobility gaps somewhat. Electric tuktuks offer alternatives to the aging Jeepneys in the Philippines, while smaller e-trikes have become a popular alternative to personal cars, too.

Conclusions

Table 1 summarizes our perspective on the role of electrifying different types of vehicles in achieving the sustainable mobility goals. There are some clearly beneficial contributions of EVs—especially in reducing transport share of local air pollution and concomitant improvement in public health. EVs are expected to reduce GHG emissions in most low-income countries, but the reduction will be modest unless accompanied by grid decarbonization. EVs could even increase GHG emissions in a few countries. Importantly, there may be more effective and cost-efficient means to achieve some of the wider air quality and GHG goals in the mega cities in low-income countries (e.g., reduce emissions from brick kilns, industries, or agricultural waste burning to improve local air quality). On the other hand, there is substantial concern on the safety side, given the popularity of the three-wheeled electric vehicles, which operate outside of the normal regulatory oversight. EVs' contributions to achieving the other sustainable mobility goals are less clear and context specific. The timing of introducing electric vehicles—especially four-wheeled cars—require special attention given the current high costs of electrification, rather high grid carbon intensity in most low-income countries, and other opportunities to better achieve some of the sustainable mobility and sustainable development goals (e.g., improving public transit and active travel facilities, planning land use, switching to hybrid vehicles, monitoring, and regulation). At the moment, ICEV replacement with EVs will reduce carbon emissions quicker in high-income countries given their better and ever-improving grid carbon intensity and large vehicle fleet, although a few niche low-income countries with low-carbon electricity system can also be suitable. In summary, low-income countries need to be judicious in their quest for vehicle electrification or banning petroleum vehicles and should prioritize according to their wider needs.

We emphasize that this article is not about challenges of vehicle electrification in low-income countries but rather about EVs' role in achieving (or not) the seven specified goals of sustainable mobility. While we focus on low-income countries, many of the arguments are likely valid for middle- and high-income countries, too (e.g., air quality, congestion, mobility divide, and mobility opportunities). New sustainable mobility goals may also be needed to account for emerging challenges, e.g., sourcing of battery material and disposal and recycling of batteries. Especially, informal lead-acid battery disposal and recycling processes in low-income countries are known to have significant adverse health impacts already. Only about 5% of lithium-ion batteries are recycled globally,[19] and their recycling in most low-income countries may not be cost-effective due to low volume.

Going forward, the following research and practice agenda is suggested for vehicle electrification in low-income countries in order to help EVs achieve the goals of sustainable mobility: (1) research into safety impacts of electric three-wheelers, improving their design and bringing their production, assembly, and operations within regulatory oversight; (2) research into air quality, marginal GHG emissions, and other unintended impacts of different types of EVs in large urban areas and prioritization of vehicle types to electrify, and in the absence of geography-specific evidence, prioritizing electrification of diesel buses, minibuses and small trucks, and motorcycles before cars; (3) research and regulation on safe disposal and recycling of batteries, especially lead-acid batteries in the short run and lithium-ion batteries in the long run; and (4) research into the optimum timing of vehicle electrification in the context of reliable electricity supply and grid decarbonization, other energy, environment and societal priorities, and associated benefit-costs trade-off. It is also crucial for policymakers to understand that EVs are not silver bullets to achieving the sustainable mobility goals, and broader strategies to achieve those goals must remain a priority while developing and implementing any EV policy. Making cars electric is a step in the right direction, but it is not the same as making travel sustainable.

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AUTHOR CONTRIBUTIONS

Z.W. conceived the article and led the writing. S.T. contributed to literature review and editing.

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The authors declare no competing interests.

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