Beyond Electric Vehicles: Recommendations for State and Municipal Policymakers to Ensure a Sustainable Transportation Future

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Executive Summary: Electric vehicles have rapidly become a primary component of the US's strategy to reduce greenhouse gas emissions and mitigate the severity of climate change. While it will surely serve an important role, EV technological advancement alone is far from a silver bullet to solve all transportation-related climate woes. On the contrary, the formidable degree of electrification necessary to meet climate goals, paired with the rapid development of clean power grids and the immense quantity of critical minerals such as lithium and cobalt needed to power this transition, is a cause for concern over the feasibility of a strategy relying fundamentally on electric vehicles. A more comprehensive, impactful, and sustainable strategy would target the car-centric foundations of US culture to make electrification more attainable while also reducing the per-vehicle resource burden and promoting more sustainable battery alternatives.

I. Introduction

Transportation is the largest contributor to greenhouse gas (GHG) emissions in the United States, primarily due to fossil fuel combustion in conventional vehicles. In 2022, it accounted for 28% of total emissions, leading electric power generation (25%) and industrial use (23%) in that year ("Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2022" 2024). As a result of this trend, electric vehicles (EVs) have gained significant attention in recent decades due to their potential role in achieving carbon-free transportation. Originally designed in the 1830s by Scottish inventor Robert Anderson (May 2010), EVs have evolved massively over the years and are now powered by rechargeable batteries which do not emit GHGs during operation. Significant advancements in rechargeable battery technology since the late 20th century have facilitated EV integration into the transportation system. Provided that sufficient low-carbon electricity is available for charging, EVs can play a crucial role in achieving carbon-neutral transportation. Although EVs are essential to any serious strategy to reduce GHG emissions, they alone cannot be relied upon to transition to a clean transportation infrastructure.

Current targets for the electrification of US transportation need to be revised to remain within the two-degree Celsius climate change target due to the excessive number of EVs that such a strategy would require (Milovanoff, Posen, and MacLean 2020). Simultaneously, massive upscaling in producing clean electricity and critical minerals such as lithium and cobalt would be required to power these vehicles (Milovanoff, Posen, and MacLean

2020). The vast magnitude of these problems results from the excessive number of vehicles on the road due to decades of privately owned vehicle (POV)-centric infrastructure development and lack of viable alternatives, and so it should be of high priority to modify these car-dependent behaviors as rapidly as possible. State and municipality policymakers have the opportunity to make several fast-acting changes to set the stage for restructuring the US transportation system.

II. Policy options

i. Mixed-use zoning to improve transportation in urban areas

Shifting individuals' reliance upon POVs towards more environmentally conscious transportation methods requires monetary and non-monetary incentive structures. However, these incentives would prove impotent if access to alternative transportation methods remains limited. Thus, non-POV transportation infrastructure must exist and be robust enough to have the proper substitution effect. The non-POV-based alternatives could include pedestrian infrastructure like sidewalks, segregated bike lanes, and mass transit opportunities, including bus and/or rail systems. Ideally, all options would be present to provide a range of options for those who have disabilities or ailments that limit physical activity. However, for these to be effective, there would need to be an increase in mixed-use zoning (MUZ), which integrates multiple types of development (residential, retail, office, etc.) into one location, significantly reducing travel.

Replacing single-family developments with MUZ has been shown to bring fiscal, social and environmental equity benefits (Call et al. 2023). Funds generated by property taxes increase by increasing the amount of economic activity and opportunities local to a municipality. For example, in Bloomington, MN, property tax revenue was approximately six times higher with the introduction of MUZ (Call et al. 2023). This increase in property tax revenue could potentially increase the quality and efficiency of any publicly provisioned mass transit systems, which would be important for the increased population density from MUZ implementation. The case study on Bloomington, MN, by Call et al. (2023) shows the significant economic benefits of MUZ as well as the social and environmental benefits. However, the risk of gentrification can undermine social benefits, and thus should be scrutinized as to reduce inequitable outcomes that arise from racial stratification (Hwang and Ding 2020).

Environmental benefits of MUZ arise from reduction in GHG emissions (Iannillo and Fasolino 2021). MUZ exists as a non-monetary incentive for residents to switch from transportation centered around POVs to transportation that results in lower per capita GHG emissions. By allowing for employment opportunities to be within reasonable walking or cycling distance, individuals are less willing to utilize POVs as primary means of transportation. As MUZ is implemented, population density increases, thereby increasing the number of people able to use public transportation and therefore increasing the economic efficiency of public transportation. Zoning ordinances should ideally be at the forefront of more sustainable urban transportation infrastructure because without efficient alternatives to POV transportation, monetary incentives in the form of tax credits or subsidies could not reach their full economic potential.

ii. Reduced battery size to minimize environmental impact

For many Americans, particularly those living far from urban centers, personal vehicle ownership is virtually unavoidable and reliance on public transportation is untenable. As the electrification of POVs has proceeded, this issue is exacerbated by consumer trends demanding larger batteries to increase their single-charge range. This causes concern from a resource conservation standpoint. For instance, projections of EV demand by 2050 suggest that the US market alone would require triple the current global lithium production. However, even assuming constant ownership rates, the lithium demand could be reduced by 29% if the average EV battery size is reduced from medium to small (Riofrancos et al. 2023). Therefore, pursuing reduced average battery sizes should be an important component of equitable transportation in the future.

Policies targeted at reducing EV battery size will likely run against the desires and tendencies of many Americans, as the concept of "range anxiety" has dominated consumer preferences and has been a

major barrier to mass electrification (Pevec et al. 2019). Needell et al. (2016) found that 87% of driving days across the US could be met using only overnight charging, even using an outdated EV range of only 73 miles. However, potential EV buyers would prefer maximized battery ranges for those few long-distance trips. A recent article in The Washington Post arguing that most Americans should look to minimize their EV battery size received over 2,000 comments, the majority of which expressed concern over a limited range for long trips (Osaka 2023). Any policy proposals aiming to reduce battery size should account for such preferences so as not to impede rapid adoption of EVs.

iii. Sustainable battery chemistries

Almost all electric vehicles currently rely on lithium-ion battery (LIB) technology, and as the demand for EVs increases, the requirement for lithium mining also increases. A key issue associated with lithium mining pertains to its environmental impacts, as the extraction process consumes substantial water and energy while potentially polluting the air and water with chemicals and heavy metals. For example, the extraction of one ton of lithium requires roughly 500,000 liters of water (Katwala 2018), potentially leading to contamination of reservoirs and associated health issues. New Jersey Assembly Resolution AR58, introduced by Rep. Scharfenberger, urges the federal government to investigate these lithium fields despite their international locations. This resolution highlights the urgency of addressing the environmental impact of lithium extraction.

Cobalt is another essential component of most LIBs that is tightly linked to environmental, economic, and social concerns. Cobalt is extracted as a byproduct from mixed nickel and copper ores, meaning its supply is tied to other commodity industries, making initiating new recovery projects costly. Currently, most cobalt is mined in African countries, with the Democratic Republic of Congo accounting for approximately 70% of the total cobalt supply ("Mineral Commodity Summaries" 2020). One of the most serious issues related to cobalt mining is using forced labor, including children and women. Several reports highlight the use of forced child labor, exposing children to chronic cobalt dust, which can cause severe lung disease (Baumann-Pauly 2023). Due to this reason, there must be a significant research focus on finding alternatives to cobalt and policies that promote such research could prove highly effective.

Sodium ion batteries (SIBs) are an alternative technology that can address the aforementioned issues by replacing lithium and cobalt with more abundant minerals. Although there has been substantial research on SIBs, they have yet to achieve energy density comparable to LIBs, which remains a major barrier to their commercialization. Some China-based companies (CATL, BYD, HiNA Battery Technology Company) have recently (2023) reported commercial SIBs suitable for EVs (PV Magazine 2024). For fast commercialization of SIBs, policies that encourage EV companies to explore sodium-based alternatives should be considered.

The "Electric and Hybrid Vehicle Battery Management Act," approved on January 8, 2024, by the New Jersey State Legislature, establishes comprehensive regulations for managing EV and hybrid vehicle batteries. The act aims to ensure environmentally sound practices in the collection, transportation, remanufacturing, reuse, recycling, and disposal of used propulsion batteries. By implementing these measures, New Jersey seeks to mitigate the environmental consequences of EV battery production and disposal, promoting a more sustainable approach to battery lifecycle management. However, the problem of environmentally harmful lithium-ion batteries continues to exist. Therefore, it is important to design policies to promote alternatives, such as SIBs.

III. Policy recommendations

i. Recommendation I: Promote denser urban planning via zoning ordinances

To achieve the numerous benefits provided by MUZ, cities should implement new zoning ordinances that promote pedestrian-oriented development, such as those implemented in Bloomington, MN (Call et al. 2023). By increasing the ability of pedestrians to safely walk through their communities and cyclists to utilize infrastructure, further tax incentives for non-POV transportation could then be implemented. The decrease in marginal tax revenue by expansion of tax incentives would likely be outweighed by taxes raised by increased population densities associated with MUZ. Such monetary incentives could include

tax rebates for public transportation and purchase of electronic bikes. The efficiency of public transportation will intrinsically improve with the implementation of MUZ, as more people will make use of it. However, for tax rebates on cycling to be effective, people must be able to safely cycle between destinations. This requires investing in segregated bike lanes to decrease collisions with vehicles (Cohen 2013). Increasing the actual safety of riders, as well as the perceived safety of cycling, further increases use by more risk-averse individuals who would otherwise cycle if safety measures were implemented.

Ordinances that cities like Bloomington, MN, have implemented can be used to guide other municipalities towards denser urban planning. For example, the city's Opportunity Housing Ordinance requires new housing projects to include a minimum number of affordable housing units and provides incentives including density bonuses (Call et al. 2023). Thus, in addition to the social benefits provided by affordable housing, such policies promote denser development to reduce urban reliance on POVs. Bloomington also provides subsidies in the form of tax increment financing which has greatly assisted in the growth of mixed-use developments (Call et al. 2023).

ii. Recommendation II: Implement weight-based fees to reduce average battery size

Examples of policy-driven solutions to oversized vehicles can be found in many domestic and foreign jurisdictions, which have implemented financial incentives for lighter vehicles. For example, Washington, D.C. recently implemented additional weight-based annual vehicle registration fees for heavy vehicles, where owners of a 2,700 kg vehicle must pay $500 per year, compared to $155 for vehicles under 1,600 kg (Segraves 2022). France has taken a more aggressive approach, with several new policies being implemented including a stiff €10 ($11.60) charge for every kg above an 1,800 kg threshold, with less stringent requirements for EVs (Shaffer, Auffhammer, and Samaras 2021).

Since a significant portion of overall EV weight is linked to battery size, we recommend states and municipalities to implement weight-based fees to manage battery sizes. Individual jurisdictions may prefer either annual or one-time fees, with either option providing the added benefit of raising funds for new transportation infrastructure. Specific weight thresholds should also vary by jurisdiction, as larger vehicles may be required for employment by many workers in rural areas. Regardless, proper care must be taken to ensure that such fees remain on par or lower for EVs than for conventional vehicles so as not to impede rapid electrification of POVs.

iii. Recommendation III: Promote alternative battery chemistries using subsidies

Given the significant steps taken by the legislature to address environmental issues associated with LIBs in the "Electric and Hybrid Vehicle Battery Management Act," it is crucial to extend these efforts to include incentives for the design and development of alternative battery sources. The Shifting Forward Vehicle Technologies Research and Development Act (H.R. 5090), introduced in the 118th Congress, emphasizes the need for innovative research and development in vehicle technologies, including significant provisions for alternative fuel vehicles and infrastructure (US Congress, 2023). This is an important step that the federal government can take to alleviate the high demand for sensitive minerals; however, states and municipalities should also act.

Subsidies are a powerful tool that states can apply to shift industrial practices. We recommend that states which are vehicle and battery manufacturing hubs apply subsidies for manufacturers who invest in alternative battery chemistries and battery recycling. States like Michigan and Nevada already provide billions of dollars in subsidies to encourage EV development (Huether et al. 2023), but additional incentives for more sustainable batteries like SIBs could be instrumental in ensuring that these options become economically viable.

IV. Conclusion

Although significant policies and investments related to transportation have been implemented into the US climate strategy recently, the vast majority have been focused on electrifying the oversized POV fleet rather than targeting the root problems of vehicle overdependence and unsustainable resource consumption. In this opinion, we have argued that states and municipalities can lead the way by pursuing several strategies to restructure transportation infrastructure to be more sustainable

without neglecting the ever-growing necessity of travel in modern society.

We recommend that state and local governments consider promoting pedestrian-oriented zoning ordinances to reduce personal vehicle use in urban areas. Additional resource conservation can be achieved by promoting smaller EV batteries via weight-based fees, reducing the quantity of critical minerals such as lithium and cobalt that must be produced. Finally, we recommend that states provide subsidies for manufacturers to explore sustainable battery chemistry. We believe that it is critical to supplement current EV technology with these and other strategies to resolve transportation-related climate issues.

References

Baumann-Pauly, Dorothee. 2023. "Cobalt Mining in the Democratic Republic of the Congo: Addressing Root Causes of Human Rights Abuses." Geneva Center for Business and Human Rights and NYU Stern Center for Business and Human Rights. https://gcbhr.org/insights/2023/02/cobalt-mining-in-the-democratic-republic-of-the-congo-addressing-root-causes-of-human-rights-abuses

Call, Brian, Linnea Goderstad, Maxwell Lohse, and Alex Menke. 2023. "Mixing Expectations: Examining the Fiscal Impacts of Mixed Use Development in Bloomington, Minnesota." https://hdl.handle.net/11299/255403.

Cohen, Emma. 2013. "Segregated Bike Lanes Are Safest for Cyclists." *CMAJ* 185 (10): E443–44. https://doi.org/10.1503/cmaj.109-4468.

Huether, Peter, Charlotte Cohn, Ben Jennings, Jasmine Mah, Ethan Taylor, Carolin Tolentino, and Shruti Vaidyanthan. 2023. "State Transportation Electrification Scorecard." American Council for an Energy-Efficient Economy. https://www.aceee.org/research-report/t2301.

Hwang, Jackelyn, and Lei Ding. 2020. "Unequal Displacement: Gentrification, Racial Stratification, and Residential Destinations in Philadelphia." *American Journal of Sociology* 126 (2): 354–406. https://doi.org/10.1086/711015.

Iannillo, Alessia, and Isidoro Fasolino. 2021. "Land-Use Mix and Urban Sustainability: Benefits and Indicators Analysis." *Sustainability* 13 (23): 13460. https://doi.org/10.3390/su132313460.

"Inventory of US Greenhouse Gas Emissions and Sinks: 1990-2022." 2024. EPA 430-R-24-004. US Environmental Protection Agency. https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022.

May, Mike. 2010. "Former Life of the Electric Car." Scientific American. August 1, 2010. https://www.scientificamerican.com/article/former-life-of-the-electric-car/.

Milovanoff, Alexandre, I. Daniel Posen, and Heather L. MacLean. 2020. "Electrification of Light-Duty Vehicle Fleet Alone Will Not Meet Mitigation Targets." *Nature Climate Change* 10 (12): 1102–7. https://doi.org/10.1038/s41558-020-00921-7.

Katwala, Amit. 2018. "The Spiralling Environmental Cost of Our Lithium Battery Addiction | WIRED." August 5, 2018. https://www.wired.com/story/lithium-batteries-environment-impact/?ref=hir.harvard.edu.

Milovanoff, Alexandre, I. Daniel Posen, and Heather L. MacLean. 2020. "Electrification of Light-Duty Vehicle Fleet Alone Will Not Meet Mitigation Targets." *Nature Climate Change* 10 (12): 1102–7. https://doi.org/10.1038/s41558-020-00921-7.

"Mineral Commodity Summaries." 2020. US Geological Survey. https://doi.org/10.3133/mcs2020

Needell, Zachary A., James McNerney, Michael T. Chang, and Jessika E. Trancik. 2016. "Potential for Widespread Electrification of Personal Vehicle Travel in the United States." *Nature Energy* 1 (9): 1–7. https://doi.org/10.1038/nenergy.2016.112.

Osaka, Shannon. 2023. "Analysis | The Obsession with EV Range Is All Wrong." *Washington Post*, July 19, 2023. https://www.washingtonpost.com/climate-solutions/2023/07/07/ev-range-anxiety-battery-myth/.

Pevec, Dario, Jurica Babic, Arthur Carvalho, Yashar Ghiassi-Farrokhfal, Wolfgang Ketter, and Vedran Podobnik. 2019. "Electric Vehicle Range Anxiety: An Obstacle for the Personal Transportation (R)Evolution?" In *2019 4th International Conference on Smart and Sustainable Technologies (SpliTech)*, 1–8. Split, Croatia: IEEE. https://doi.org/10.23919/SpliTech.2019.8783178.

Riofrancos, Thea, Alissa Kendall, Kristi K. Dayemo, Matthew Haugen, Kira McDonald, Batul Hassan, Margaret Slattery, and Xan Lillehei. 2023. "Achieving Zero Emissions with More Mobility and Less Mining." Climate and Community Project. http://www.climateandcommunity.org/more-mobility-less-mining.

Segraves, Mark. 2022. "DC Vehicle Registration Will More Than Triple for Some SUVs, Trucks by 2024." *NBC4 Washington*, May 28, 2022. https://www.nbcwashington.com/news/local/dc-vehicle-registration-will-more-than-triple-for-some-suvs-trucks-by-2024/3063961/.

Shaffer, Blake, Maximilian Auffhammer, and Constantine Samaras. 2021. "Make Electric Vehicles Lighter to Maximize Climate and Safety Benefits." *Nature* 598 (7880): 254–56. https://doi.org/10.1038/d41586-021-02760-8.

"Sodium-Ion Batteries – a Viable Alternative to Lithium?" 2024. PV Magazine. March 22, 2024. https://www.pv-magazine.com/2024/03/22/sodium-ion-batteries-a-viable-alternative-to-lithium.

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