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EVs Are Not the Answer: A Mobility Justice Critique of Electric Vehicle Transitions

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Within climate–energy–transport scholarship and professions there is a growing consensus that electric vehicles (EVs), which include personal cars, sport utility vehicles (SUVs), vans, and pickup trucks, are essential for decarbonizing mobility. This article urges caution and pause before an EV lock-in and calls on geographers and other scholars, professionals, and sustainability advocates to consider the multiscale environmental and social problems associated with EVs. The article begins by reviewing the mainstream assumptions about mass EV uptake, with particular emphasis on projections forecasting more, not fewer, cars in the future. Using a mobility justice framework, I ask who is making these assumptions and why and discuss the influence of liberal economic theory on future projections of EVs. I next consider assumptions about the environmental efficacy and decarbonization potential of mass EV uptake and review how EV production and consumption might escalate rather than reduce global resource and energy demand. I also scale down to cities and describe how EVs will lay claim to many of the same spaces designated for green mobility, such as cycle tracks, bus lanes, and compact, walkable spaces. The conclusion proposes research questions to consider with regard to EVs, future transportation, future geographies, and future carbon emissions. *Key Words: decarbonization, electric vehicles, mobility justice, transport geography, urban geography.*

在气候-能源-交通学术研究和专业领域，有一种日益普遍的共识，那就是电动汽车（EV）（包括个人轿车、运动型多用途车（SUV）、面包车和皮卡车）对于降低汽车碳排放量至关重要。本文敦促在锁定电动汽车之前应谨慎行事，并呼吁地理学家和其他学者、专业人士，及可持续发展的拥护者们考虑电动汽车相关的多尺度环境和社会问题。本文首先回顾了主流的对电动汽车使用量的假设，并特别强调了对未来汽车数量增加（而非减少）的预测。本人还采用流动性正义框架，询问了谁在做这些假设及其原因，并讨论了自由经济理论对未来电动汽车预测的影响。其次，本人考虑了与大批采用电动汽车的环境效率和脱碳潜力相关的假设，并审视了电动汽车生产和消费可能如何增加（而非减少）对全球资源和能源的需求的)。最后本人还将范围缩小到城市，并描述了电动汽车将如何占用许多指定用于绿色出行的空间（例如自行车道，公交专用道以及紧凑，可步行的空间）的。结论提出了电动汽车、未来交通、未来地理位置和未来碳排放等相关的待研究问题。 *关键词：脱碳，电动汽车，流动性正义，运输地理学，城市地理学。*

Hay consenso creciente en la erudición y las profesiones relacionadas con clima–energía–transporte en el sentido de que los vehículos eléctricos (EVs), incluidos carros personales, vehículos para uso deportivo (SUVs), furgones y camionetas, son esenciales para la descarbonización de la movilidad. Este artículo reclama cautela y pausa antes de llegar a la monopolización de los EV, y alerta a geógrafos y otros académicos, profesionales y defensores de la sustentabilidad que se considere seriamente el carácter multiescalar de los problemas ambientales y sociales asociados con los EVs. El artículo empieza con la revisión de supuestos convencionales acerca de la adopción masiva de EV, con énfasis particular en las proyecciones que pronostican más carros que menos en el futuro. Usando un marco de justicia de la movilidad, pregunto quién está a cargo de formular estas suposiciones, y por qué, y discuto la influencia de la teoría económica liberal sobre las proyecciones futuras de los EVs. Considero después las suposiciones acerca de la eficacia ambiental y el potencial de descarbonización por adopción masiva del EV y reviso cómo la producción y consumo del EV podrán disparar en vez de reducir la demanda global de recursos y energía. También, me pongo en el lugar de las ciudades y describo cómo los EVs reclamarán muchos de los mismos espacios designados para la movilidad verde, tales como las rutas para ciclistas, los carriles para buses y los espacios compactos caminables. La conclusión propone preguntas de investigación para considerar en relación con los EVs, lo mismo que sobre transporte futuro, geografías futuras y emisiones futuras del

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carbono. *Palabras clave: descarbonización, geografía del transporte, geografía urbana, justicia de movilidad, vehículos eléctricos.*

Within climate–energy–transport scholarship and professions there is a growing consensus that electric vehicles (EVs[1]), which include personal cars, sport utility vehicles (SUVs), vans, and pickup trucks, are essential for decarbonizing mobility (International Energy Agency [IEA] 2018; Noel et al. 2018; Sovacool and Axsen 2018; Sperling 2018; Kuby 2019). Propelled by electric motors and charged by electrical grids, EVs amount to only 1 percent of the estimated 1 billion cars worldwide, but governments in the world's largest car markets (e.g., California, China, and Europe) are implementing public policies and subsidies for mass EV uptake, and car manufacturers are allotting hundreds of billions of dollars to new EV production (Bloomberg New Energy Finance 2017; Alix Partners 2018; IEA 2018; California Air Resources Board [CARB] 2019b). New global supply chain logistics, renewable (and nonrenewable) energy supplies, and electrification of urban spaces for EV charging are being marshaled with enormous public intervention (Heywood and Mackenzie 2015; Greene 2017; Keith, Houston, and Naumov 2019; Keith and Knittel 2019; Kuby 2019; Sovacool, Abrahamse, et al. 2019). This points to a self-reinforcing, path-dependent, multidecade "lock-in" of EVs piggybacking on automobility, or the centering of society and everyday life around the car and its spaces (Dennis and Urry 2009; Sovacool and Axsen 2018).

There is skepticism, and in this article I urge a pause before committing to an EV lock-in. Between 2020 and 2030, more rapid and far-reaching transitions will be needed for decarbonization than previously understood, and the rush toward EVs might divert planetary resources while doing little to mitigate global warming (Bergman 2017; Bergman, Schwanen, and Sovacool 2017; Intergovernmental Panel on Climate Change [IPCC] 2018; Anable and Goodwin 2019; Herrington 2019). Geographers and other scholars, especially those focused on climate, energy, and transport justice, as well urban planning and policy, should carefully scrutinize the rapid acceleration toward EV uptake and the claims and assumptions used to legitimize EVs.

The article begins by reviewing the mainstream assumptions about mass EV uptake, with particular emphasis on projections assuming more, not fewer, cars in the future. I ask who is making these assumptions and why. I then consider claims about the environmental efficacy and decarbonization potential of mass EV uptake, and review how EV production might escalate rather than reduce global resource and energy consumption. After reviewing the harms of EV electricity consumption, I scale down to cities and describe how EVs will lay claim to many of the same spaces designated for green mobility, such as cycle tracks, bus lanes, and compact walkable spaces, and how a rush to mass EV uptake in the world's cities threatens to usurp the deeper decarbonization potential of green mobility. I also discuss how EV policies might contribute to carbon gentrification, or the displacement of lower income residents from desirable, livable sections of cities where EV infrastructure will first roll out. Finally, the conclusion proposes critical geographic research on EVs and future transportation.

Throughout the article I use a newly emergent mobility justice framework adopted from Sheller (2018) and originating in sociology and mobility studies. Mobility justice fuses fixed-in-place transportation justice (demanding equal access in cities, reducing localized environmental harm) with the multiscaler mobilities paradigm (everything is in motion and motion is shaped by political power; Cook and Butz 2019). Mobility justice is concerned with governance and control of movement and how political power shapes the patterns of unequal mobility and immobility in the circulation of people, resources, and information at different geographic scales. Mobility justice encourages us to ask who promotes and benefits from EVs and how politics is embedded in assumptions about EVs.

A key component of mobility justice is "scaler fluency," providing sharper relief in delineating how the environment and social impacts of mass EV uptake might shift between geographic scales (Sheller 2018). In this way, mobility justice resembles energy justice, a new analytical approach toward hidden and distant injustices connected to the full life cycle of energy production and consumption (Jenkins 2018; Healy, Stephens, and Malin 2019; Sovacool, Hook, et al. 2019). For example, EVs might promise cleaner air from localized car traffic, perhaps benefiting lower income neighborhoods adjacent to highways, but a more transparent and capacious analysis must include geographically distant but harmful battery production and electricity generation, aspects of EV mobility often rendered invisible by boosters. Borrowing from critical geographer Neil Smith, mapping claims about EVs requires that we "jump scale" to account for displaced emissions and environmental impacts that bring mobility injustice—people harmed by the mobility of others—as well as how politics shapes justice and injustice at different geographic scales (Newstead, Reid, and Sparke 2003; Healy, Stephens, and Malin 2019).

Mobility justice offers a totalizing framework for considering deep decarbonization and sustainable transitions in transport by pulling together geographic scale and multiple approaches to justice, from global climate justice, to local environmental and transport justice, to energy justice, and to social and spatial justice in cities. It is distinctive from these other justice frameworks because it foregrounds movement; for example, expanding from a narrow focus on the energy demand and emissions of automobiles to how the configuration of space through political power compels or limits automobile ownership and use. Bounding conceptually around mobility justice leads us to question the hegemony of automobility rather than simply propulsion technology or fuel choices.

Employing a mobility justice approach, I gather, analyze, synthesize, and critique rapidly expanding literature on EVs, specifically asking the following: What are narratives of the future of EVs? Who defines these futures? How are production and consumption of EVs (and concomitant electrical systems) considered? Because EVs rely on a high-density charging infrastructure likely to be concentrated in cities, I also examine narratives of EVs and the future of cities. A review of scholarly journals was conducted in 2018 and 2019 and initially included an expansive keyword search using university library databases. Not surprising, many transport-, energy-, and environment-themed journals regularly publish papers on EVs. Beyond scholarly journals, the California Energy Commission (CEC) houses that state's aggressive EV policy discussion and provides a rich gateway including white papers, public meetings, listening sessions, and industry perspectives. Other important sources include the IEA, the European Environment Agency (EEA), the U.S. Department of Energy (USDOE), major environmental organizations and transportation nongovernmental organizations in the United States and Europe, and media venues such as Bloomberg's New Energy Finance.

The scholarly and nonscholarly literature on EVs is exploding rapidly, and it is unwieldy. Almost every day new material about EVs is generated, yet notably there have been few critical approaches in scholarly and professional EV research. There are also few critiques from a mobility justice perspective (with Sheller [2018] as an exception). The lack of a critical approach is problematic because EV boosters are asserting sweeping claims on the future, and these might eclipse other pathways to deep decarbonization such as green mobility and compact cities. A summary of these claims and assumptions is provided in Table 1, with mobility justice critiques elaborated in the remainder of the article.

EVs and Assumptions about Future Mobility

The window for humanity keeping within stable and livable bounds (1.5°C–2 °C) of warming is 2020 to 2030, and mass EV uptake has been hitched to this time frame (IEA 2018; IPCC 2018). Yet during the decade when global society must radically ratchet up efforts to reduce transport emissions, 2020 to 2030 might instead see more cars and more driving, not fewer cars and less driving. Future growth in cars and car usage is baked into EV projections, and this needs scrutiny.

For example, California, considered a global leader on climate mitigation and EV promotion, targets reductions to 40 percent of 1990 emissions by 2030 and identifies mass EV uptake—5 million zero emissions vehicles (ZEVs, mostly EVs) by 2030—as necessary to reach the target (with 50 percent renewable electricity generation; CARB 2019b). Yet California, with more than 25 million cars in 2019, forecasts 5 million more cars in 2030 and 10 million more by 2040 and assumes that today's high rates of driving stay the same in the future (CARB 2019a; CEC 2019c).

Globally, the IEA, which is referenced by many EV boosters, asserts that aggressive government intervention is needed to align mass EV uptake with rapid decarbonization (Creutzig 2016; IEA 2019; Sovacool, Abrahamse, et al. 2019). The IEA's

Table 1. Summary of claims, assumptions, and mobility justice critiques of EVs

Claim	Assumption	Mobility justice critique
High rates of future automobility can be sustainable with EVs	Doubling of global car fleet, from 1 billion in 2018 to 2 billion by 2040	Wealthy states and nations remain car dependent despite histories of disproportionate cumulative and displaced emissions
	Distances of driving remain high and increase	Rebound effect: Escalated driving due to subsidies and privileges for EVs
		Vehicle-to-grid charging compels more driving to balance electrical grid
		Break-even point: Emissions are "green" only when EV is driven great distances
EV production and consumption is sustainable	EVs are zero emissions	EV life-cycle emissions are excluded from most carbon inventories
		Local EV uptake ignores emissions in global supply chain
	Resources for EVs are available and plentiful	EVs lead to exhaustion of many planetary resources
		Production and consumption for EVs increases global conflict
EV energy supply is sustainable	Electricity for EVs will be low carbon and renewable	EVs use significant fossil fuel–generated electricity to 2040 and beyond
		Renewable energy for EVs will supplement rather than offset fossil fuels
	Electricity capacity for EVs will be plentiful	Electricity demand will increase, requiring more power generation
		Like EVs, renewable energy at scale exhausts planetary resources and generates conflict
		EV competes with claims on future renewable electricity such as rail and air conditioning
EVs as new urban policy	Cities are a natural fit for EVs	Charging infrastructure competes for space and public funding dedicated to green mobility
		Decades of overlap between EVs and ICE exacerbates competition for urban space
		Charging sprawl: EVs require abundant parking and lower density housing
	EV subsidy can be equitable	Carbon gentrification: Charging infrastructure in urban cores contributes to displacement and inequity

Note: EV = electric vehicle; ICE = internal combustion engine.

(2019) optimistic scenario is that all of the world's nations and automobile manufacturers will adopt EV mandates and policies similar to California's such that by 2030 15 percent of the world's 1.66 billion cars, or 250 million, will be EVs. Beyond 2030, the IEA (2018) promotes a "Future Is Electric Scenario," with half of the world's two billion cars electrified in 2040.

The USDOE's National Renewable Energy Lab, which examined EV charging futures, envisions a high uptake scenario of 240 million EVs nationwide, 84 percent of the total fleet in 2050, and the same high rates of driving as today (USDOE 2018; Wood 2019). In these forecasts and projections, the fundamental assumption is almost a doubling of cars worldwide by 2040, with EVs gradually increasing as a proportion (Sperling and Gordon 2009; Hove and Sandalow 2019).

Studies also assume similar or higher driving distances in the future compared to present-day driving (Needell et al. 2016; IEA 2019; Wood 2019). Bastani, Heywood, and Hope (2012) projected average driving distances for the United States to increase in 2020 to 2030 and grow through 2050, albeit at a declining growth rate. Some studies predict that by 2050, even if autonomous vehicles (AVs) also proliferate, household car ownership rates will remain as they were in 2019 and private car driving will increase 10 percent, even with a ride hail fleet (e.g., Uber) overlaid (CEC 2019a). A rebound effect of escalated driving might unfold if public policies privilege EVs with free parking, rebates, and favorable taxation and the perception that the EV is zero emissions (Needell et al. 2016; Greene 2017; Anable and Goodwin 2019).

Proposed vehicle-to-grid (V2G) charging (using EV batteries as mobile electricity sources) and efforts to balance renewable energy with grid stability might necessarily compel more driving, not less, by EV owners (Kester 2018). Solar and wind energy are intermittent and have different peaks not matched with household electricity demand, with peak solar generation at midday and peak wind depending on local conditions. Peak household electricity demand, however, is in the evening. With V2G, peaks in production and demand would be balanced with charged EVs storing surplus renewable electricity and later delivering it to households. EV owners would need to reliably and habitually plug in while at work or shopping, compelling routine driving as necessary to stabilize the electrical grid and balance energy loads (Colantuono 2015; Noel et al. 2018). Because the battery supplies power to a household, V2G might also induce preference for car ownership rather than shared mobility often supported by some EV boosters (Sperling 2018).

Depending on the proportion of renewable energy in the grid, EVs must also be driven frequently to reach a "break-even point" whereby the high production-related emissions of EV batteries (see later) are canceled out. Setting aside that this only addresses carbon emissions (and not other toxins in the EV life cycle), the assumption is that the more an EV is driven, the lower the impact of production-related emissions on the total life cycle emissions of an EV (Ellingsen, Singh, and Strømman 2016; Egede 2017; EEA 2018). Theoretically, an EV charged entirely by renewables has the lowest break-even point (one study estimated roughly 31,000 miles [50,000 km]; Hydro-Quebec 2016).

The IEA (2019) posits that in a mixed fossil fuel–renewable grid, if a typical midsize EV is driven 9,300 miles annually (15,000 km) it will break even between one and a half and four years, depending on the size and make of the EV. In Europe a typical EV might have a break-even point of 93,000 miles (150,000 km), just shy of a comparable gasoline car and indistinguishable from a diesel car (Hawkins et al. 2013). Significantly, 93,000 miles is also the distance a typical EV battery lasts under optimal conditions (IEA 2019). Under real driving conditions (considering topography, congestion, and weather conditions), typical EVs would need battery replacement much sooner, which would negate the break-even point. V2G also reduces battery longevity. Larger, upscale, luxury EVs are more durable, with a potential use life of between ten and fifteen years or 178,000 miles, requiring a second, even third replacement battery, negating break-even (Roosen, Marneffe, and Vereeck 2015; USDOE 2016a; Jenn et al. 2019). Some EV drivers, once crossing the theoretical break-even point, might assume zero emissions and rebound into more driving (Greene 2017).

The cascade effect of more cars and more driving manifests in additional ways. In wealthy countries many households buying EVs also keep a second conventional gasoline car to overcome range anxiety and charging times (fear of being stranded with a depleted battery and the many hours it takes to fully charge EV batteries; Needell et al. 2016; USDOE 2016b; Jensen and Mabit 2017). In other cases there is evidence that EV households substituted driving for what had been short-distance cycling trips (Jensen and Mabit 2017).

In the IEA's aspirational EV scenario for 2030, 85 percent of the world's 1.66 billion cars would still be conventional gasoline vehicles. The lag time of "vehicle fleet turnover" means that conventional gasoline cars remain for many decades before a full transition to EVs (Keith, Houston, and Naumov 2019; Keith and Knittel 2019). With more cars and more driving as the fundamental assumption in EV narratives, decades of messy overlap with the incumbent gasoline car system will likely reproduce and intensify the existing environmental problems of automobility. Why is there little to no modeling of EV futures that forecast fewer cars, even though such a scenario can be analyzed by IEA and other outfits (Creutzig 2016)?

EVs and Mobility Justice

A mobility justice framework considers the power embedded in the assumptions underlying projections of more cars and more driving, and this means questioning traditional (neo-) liberal theories of mobility informing these assumptions. Projections of future automobility are biased by economically liberal, market-based assumptions that future rational choice and consumer preference will remain similar to present-day market preferences (Creutzig 2016). Bias includes an "unreconstructed logical positivism" whereby adherents claim that the world is totally knowable through data collection and analysis, that data do not lie—algorithms are free from politics—and that the data show that many people simply want cars (Greenfield 2013). It follows that EVs will alleviate people's concerns about the impact of driving on the environment, thus leading them to drive more.

Economic liberalism, conflated with normative ideas about freedom and automobility, biases expert judgment toward technological solutions like EVs rather than mode shift to other alternatives like expanding transit or cycling. Assuming increased personal income resulting from continued economic expansion, billions of autonomous individual consumers of the future must be provided the same comfort, price, and convenience experienced in cars today, while enabling business as usual for private automobility and the (neo-) liberal economic growth paradigm (Linton, Grant-Muller, and Gale 2015; Bergman 2017). The promotion of mass EV uptake reflects the relentless search for the most painless decarbonization strategy that enables high rates of mobility (Bergman, Schwanen, and Sovacool 2017). The liberal hue in assumptions has led to a collective consensus among many climate, energy, and transport scholars and professionals that EVs are inevitable and that mass EV uptake is the best and most obvious pathway to decarbonization of transport (Noel et al. 2018; Sperling 2018; Anable and Goodwin 2019; IEA 2019; Sovacool, Abrahamse, et al. 2019).

It follows that green mobility policies to reduce driving such as car taxes, pricing or rationing of parking or roadway use, compact cities, and driving restrictions, although preferable to mass EV uptake, would invite political backlash and politicians would turn to self-preservation through accommodating automobility (Heywood and Mackenzie 2015; Berkeley et al. 2017; Sovacool and Axsen 2018). The EV has been politically determined as the winner of the future, and mode shift and a deeper discussion of a postcar society have been marginalized (Bergman 2017; Bergman, Schwanen, and Sovacool 2017; see also Dimatulac and Maoh 2017; Morton et al. 2018).

EV researchers such as Sovacool, Kester, et al. (2019a) also urge including deeper moral and ethical issues in analysis of EV impacts. This includes issues of power and asking who is promoting EVs and why. Specifically, the hypermobility of "kinetic elites" is frequently celebrated in EV promotion (see, e.g., the Sierra Club's "SUV without Shame" narrative; Birtchnell and Caletrío 2014; Motavalli 2019). Kinetic elites, a relatively small percentage of the world's population, live in wealthy nations and global cities and are high income, highly mobile, and disproportionate carbon emitters (Sheller 2018). Expanding beyond the elite 1 percent outlined in Birtchnell and Caletrío (2014) to include the broader global upper middle class, kinetic elites travel between elite mobility zones such as gentrified urban cores and clean, green, park-like suburbs and are increasingly connected instantly and globally with mobile phones and communications and ultimately via the "smart city" and Internet of Things (Greenfield 2013; Sheller 2018). Since 2010, kinetic elites have been the early adapter target market for EVs and stand to benefit most from EV subsidies and privileges (Anable and Goodwin 2019; Sovacool, Kester, et al. 2019a).

Mass EV uptake will be geographically uneven, with EV sales in higher income, higher educated, wealthier sections of metropolitan areas, with stronger environmental politics that ironically block establishment of new energy capacity (National Research Council [NRC] 2015). Coffman, Bernstein, and Wee (2017) described an "EV oriented consumer" in the United States as upper income, educated, and concerned about their image with respect to climate and environment. Early evidence of EV uptake has shown that, in the United States, 78 percent of individuals receiving EV tax breaks in 2016 were in the top income bracket making over $100,000 annually (Congressional Research Services 2019). In the United Kingdom, EV uptake is primarily in higher income, homeowning clusters and includes the core of London where an EV can allow drivers to circumvent the congestion toll (Morton et al. 2018).

In self-identified EV capitals like the San Francisco Bay Area, where Tesla and an array of EV firms are located, the EV is part of branding for new luxury housing and employee benefits such as free workplace charging at companies like Facebook. There EVs are marketed to kinetic elites as a greening of mobility and individualist action to mitigate global warming (White and Sintov 2017). In Nordic countries, EVs are linked to conspicuous consumption and symbolize a socially responsible environmental status (Sovacool et al. 2018; Nordlund, Jansson, and Westin 2018; Sovacool, Kester, et al. 2019a, 2019b).

Much of the marketing for EVs takes on a neoliberal hue in making EVs compelling for the kinetic elite. Consultants for the EV industry especially steer EV uptake toward luxury EVs. Public perception of range anxiety leads to promises by EV boosters of longer range but heavier batteries, resulting in higher production costs and necessitating a target market of higher end buyers. Luxury EVs bring more profit to the manufacturer, and following liberal theory, the manufacturer pours profit into innovation into improves mass EV technology (Chawan 2019).

Many EV manufacturers focus on premium cars and SUVs. In the United States, Ford Motors and Amazon invested $500 million and $700 million, respectively, in luxury EV startup Rivian, producing a supersize prototype EV pickup truck, pointing to the insatiable SUV and light truck markets (Chawan 2019). The Rivian, praised as "spectacular and beautiful" by one prominent environmentalist and California environmental regulator, points to EVs' battery range as a new emergent form of mobility stratification (Monahan 2019). Elites who want to appear green in their consumer choices will afford longer range luxury EVs as lower classes are left behind.

In the United States, EVs are promoted by what Klein (2014) called "big green," the large, liberal, promarket environmental organizations such as the Environmental Defense Fund (2019), Natural Resource Defense Council (2019), and Sierra Club (2019). These organizations commission boosterish reports and lobbied the Obama administration (2009–2017), which is credited for kick-starting EV uptake with tax rebates, emissions standards for future new cars, and research on EV batteries.[2] Many governors and mayors promote EVs, and some political supporters of a green new deal urge the creation of an EV industrial policy in the United States (Walker 2018; Sanders 2019).

The momentum for EVs is growing and politically powerful. Yet globally, mass EV uptake will be uneven and inequitable, with EVs proliferating in high-income strata of high-income countries by the 2030s but with little to no EV uptake in low- and middle-income countries (International Transport Forum [ITF] 2018a). Some modest level of EVs might have a place in the future, but mass EV uptake is far from assured, and counternarratives argue for measured restraint toward EVs (Anable and Goodwin 2019).

EV Production

In the decade (2020–2030) when global society must ratchet up efforts to reduce transport emissions, mobility justice necessitates reexamining the premise that EVs will be good for the climate and planet. Just as the extraction, processing, and transport of energy can be made transparent to understand the "embodied energy injustices" of energy systems like coal and fracking, EVs must have the same level of scrutiny (Healy, Stephens, and Malin 2019). Similarly, a "whole systems" approach of energy reveals numerous hidden and distant factors at different scales that must be included in the EV narrative (Sovacool, Hook, et al. 2019). Recent skepticism about EVs suggests that mass EV uptake is not only undesirable but physically impossible within the bounds of known mineral resources and would dramatically escalate global energy consumption (Herrington 2019). The rush to mass EV uptake could be a huge miscalculation, and a lack of scaler fluency in the understanding of EV emissions and environmental impacts must be addressed.

In California, with one of the most aggressive EV policies, inventories of greenhouse gas (GHG) emissions from transport include only vehicle tailpipe or electricity emissions generated within the state and do not account for overseas vehicle manufacturing, which for an EV is significant (CARB 2019a, 2019b). This biases EV benefits locally and ignores EV impacts globally (NRC 2015). Sperling's (2018) influential three revolutions (EVs, AVs, and ride-hail) thesis, which has affected policy formulation in California, does not include discussion of the potential negative environmental impacts of battery production and optimistically suggests that future worldwide electricity production will be 100 percent renewable (including reviving nuclear energy, which is far from certain).

When extending emissions analysis upstream and well-to-wheel to extraction, distribution, and transmission of electricity, this expands the geographic scope of impacts but much uncertainty remains (Greene 2017; Union of Concerned Scientists 2018; USDOE 2019b). In certain instances EVs compare favorably, whereas in others they compare unfavorably, and this largely depends on the electricity mix. The omission of manufacturing vehicles and batteries, energy production facilities, and disposal means that there is considerable uncertainty about the true carbon footprint of EVs (Roosen, Marneffe, and Vereeck 2015; USDOE 2016a, 2019a; Sovacool and Axsen 2018). Emphasis on GHG emissions overlooks localized toxicity to humans, freshwater ecotoxicity, freshwater eutrophication, metal depletion impacts, and other problem shifting (Hawkins et al. 2013). For example, rare earth elements (REEs), key to EVs, are found in very low concentration within other minerals and are accompanied by thorium, a radioactive element that must be carefully handled to avoid contaminating the environment.

There are more than 140 components and subcomponents within a typical car, most of which are similar regardless of whether it is an EV or conventional gasoline car (Hawkins et al. 2013). Both contain large amounts of steel, lead, plastics, aluminum, and various chemicals that contribute to high GHG emissions and are part of a vast operational landscape of geopolitical supply chains, displaced emissions, and military conflict (Greene 2017; Sheller 2018). Both propulsions have synthetic rubber tires, with black carbon, sulfur, silica, and other toxins (Chester and Horvath 2009). Both propulsion systems also contain an array of nanomaterials for electronics that have very toxic manufacturing processes and produce GHGs emissions with much greater global warming potential than the carbon from burning fossil fuels.

When full life cycle analysis of EVs includes the battery, electric motor, and "lightweighting" (making lighter materials for extension of range and compensating for heavy battery), EVs become more carbon intensive than many boosters acknowledge (Hawkins et al. 2013; EEA 2018; USDOE 2016a, 2019a). During manufacturing, EVs produce almost twice as much GHGs, toxins harmful to humans, and toxins harmful to air and water compared to conventional cars, mainly due to the battery and to electronic equipment, as well as using more aluminum (Hawkins et al. 2013).

The globalization of resource extraction and EV supply chains contributes to confusion and uncertainty in life cycle inventories for EVs, and this should give further pause to boosterish claims. For example, USDOE (2019a) pointed out that two thirds of EVs sold in the United States between 2010 and 2018 were assembled in the United States, but only one third of the components were sourced in the United States. Location matters, and because most batteries are produced and battery supply chains exist outside of the United States or Europe, there is uncertainty about the scale of their carbon footprint and environmental impacts. With few exceptions, all EV batteries for the U.S. market, the most carbon-intensive part of an EV, are manufactured outside of the United States.

There is a dearth of supply chain intelligence, and much of the manufacturing process occurs beyond the regulatory jurisdictions where emissions regulations are considered strongest (EEA 2018; Synthesis Partners 2019). A study of Chinese battery production pointed out that GHG emissions from battery production in China were up to three times higher than if the battery were produced in the United States (EEA 2018). The IEA (2019) further acknowledged that the supply chain for manufacturing batteries and the disposal of batteries contain many unknowns.

Global extraction and processing of lithium, cobalt, and REEs, all raw materials critical to batteries and to enable miniaturization of electronics and motors in EVs, have especially vexing environmental and geopolitical implications for mobility justice (Levy, Rosen, and Iles 2017; Sheller 2018; IEA 2019). Mass EV uptake means future shortages and conflicts over these and other strategic minerals (IEA 2018; Herrington 2019). In IEA's (2019) EV uptake scenarios for 2030, worldwide demand for cobalt and lithium will exceed current supply, and if 15 percent of all cars in 2030 are EVs, nickel supply will also be depleted. Based on existing foreseeable battery technology and global resource availability in 2018, a transition to 31.5 million EVs in just the United Kingdom would consume two times the world's cobalt production, three quarters of the world's lithium production, half of the world's copper production, and the entire world's production of REEs neodymium and dysprosium (Herrington 2019). Substitutes for lithium exist but would not be capable of the capacity and quality of lithium. Batteries might increasingly use cathode chemistries that are less dependent on cobalt, but these batteries would use more nickel, which the IEA (2019) warns faces scarcity by 2030.

Global EV supply chains are not just carbon intensive and toxic but shrouded in conflict, potentially escalating neocolonialism (Sheller 2018). Most of the world's supply of REEs comes from only a handful of sources because of environmental concerns over mining and processing (Matsumoto 2019). A new scramble for "conflict minerals" is poised to accentuate more than a century of messy and violent oil geopolitics. In the Democratic Republic of Congo, which supplies 60 percent of the world's cobalt (and 90 percent of cobalt for Chinese battery production in China), there is well-documented but persistent exploitation, violence, and environmental degradation in the mining industry (Frankel 2016a).

A mining boom in the "Lithium Triangle" (Argentina, Bolivia, Chile) in South America stoked political conflict (Frankel 2016b). Bolivia's anticapitalist politics that means state-run enterprises conflict with the extractive agenda of global mining corporations. In 2018, U.S. mining interests balked at developing Bolivia's mines, choosing the more favorable business climate in neighboring Chile, but based on the increased demand, pressure will build to access Bolivia (Draper 2019).

China has been one of only a few nations willing to tolerate the environmental impacts of processing REEs and thus holds a near global monopoly on REEs (Levy, Rosen, and Iles 2017). In 2018, China processed 70 percent of global REEs and 85 percent of the most critical high-purity REEs (Matsumoto 2019). As a result of geopolitical trade and competition among powerful militarized nations like China, the United States, and Russia, Bloomberg New Energy Finance warns of future volatility of metal prices (Logan Goldie-Scot 2019).

Replacing conflict minerals with extraction in places with strong environmental laws is difficult. California, the lead consumer of EVs in the United States, also leads in rendering invisible the true environmental impact of EVs. In late 2019 there was no in-state extraction of raw materials for EVs, despite the large mothballed REE mine at Mountain Pass in the Mojave Desert, which was shuttered for environmental concerns.[3] Anticipating U.S. uptake of EVs, primarily in California over the next decade, an REE processing plant has been proposed in Texas, a U.S. state with lower environmental standards than California (Matsumoto 2019). Switching to an EV lock-in, even if partial, means reproduction of the automobile's historic dependency on conflict minerals and extends dangerous dependency on militaries. In the United States, an EV transition involves shifting the historical "American way of life" centered on cheap oil and automobility to an "EV way of life" with new colonial ventures to secure resources (see Huber 2013; Levy, Rosen, and Iles 2017).

EVs and Energy Consumption

Cross-cutting the global-scale resource limits and geopolitics of EVs, there remains uncertainty about electricity capacity, availability of renewable energy, and competition for future renewable energy capacity between different transportation modes and sectors of consumption. If mass EV uptake approached 1 billion cars by 2040 (half of the projected world total), one third of total global energy would need to be electric, up from 20 percent in 2018 (IEA 2018). More modest EV uptake might result in 5 percent expansion in global electricity consumption in 2040 but still presumes high numbers of gasoline cars (Bloomberg New Energy Finance 2017). The equivalent of fifty new large utility-scale power stations would be needed for Europe to approach 80 percent electrification by 2050, and the United Kingdom would need 20 percent more electricity generating capacity (EEA 2016; Herrington 2019). German household electricity consumption would double by 2030 (for EV households; Jochem, Babrowski, and Fichtner 2015).

The USDOE (2018) acknowledged a "dramatic increase in electricity demand" (38 percent increase) if up to 84 percent of U.S. cars electrified by 2050. A lower 20 percent EV uptake rate in the United States (about 38 million cars based on 2011 data) brings a 5 percent increase in capacity needs, but in some regions (like California) the need would be higher. Assuming that ownership rates and driving distances remained constant, California would have to ramp up electricity production by 47 percent to reach full EV deployment, or the equivalent of electricity for 12 million homes in that state (Davidson et al. 2018). Texas would need increased electricity production equivalent to 11 million homes to accommodate full EV transition.

Decarbonization through EVs would also require a 100 percent renewable energy system, with wind energy demonstrating the lowest carbon emissions per mile (when factoring in upstream energy emissions from building and transmission; USDOE 2016a, 2019a). Yet no such system exists, and in the window of 2020 to 2030, few places have 100 percent renewable targets. California, with one of the world's most aggressive renewable mandates, expects 50 percent of electricity to be renewable by 2030 (including expanded capacity), and EVs will be using electricity from fossil fuels at least through the 2040s.

Many projections of energy futures show fossil fuel electricity generation remaining significant in many parts of the world for many more decades, meaning that if mass EVs uptake is locked in, EV space will remain reliant on fossil fuels and only supplemented by renewable energy (Hawkins et al. 2013; Greene 2017; EEA 2018). At best the United States is expected to transition to 13 to 15 percent renewable by 2030, with almost 70 percent split between coal and natural gas and the remaining generated by nuclear (USDOE 2016a). In the Mid-Western, Southern, or Northeastern United States, operational emissions for EVs would be greater than conventional cars because of high coal and natural gas content in electricity generation (USDOE 2016b, 2018).

EV-oriented states like California, as well as academic and industry EV boosters, assume that 100 percent renewable energy can be scaled up to meet the capacity and demand (Sperling 2018). Yet there are few clearly mapped buildouts of renewable energy to the scale of future electricity demand. California started to map what this might look like, but the pathway is not clear (CEC 2019b). Electricity supply will tighten in places like California where hydroelectric generation is expected to decline due to retreating snowpack as a consequence of global warming. Wind, which provides 6 percent of that state's electricity on windy days, might soon reach buildout as all viable mountain passes are developed (CARB 2019b). There are no large wind arrays in the pipeline within the state, and offshore wind farms might have potential but only if economics and opposition from wealthy coastal property owners are overcome.

Just as with EVs themselves, there are resource limits for the feedstock of metals and minerals for wind and solar installations (Herrington 2019). All photovoltaic systems currently on the market are reliant on one or more raw materials classed as critical or near critical by the European Union, USDOE, or both (high-purity silicon, indium, tellurium, gallium) because of their natural scarcity. Both wind and solar infrastructure require substantial steel, aluminum, cement, and glass.

Parallel efforts to scale up renewables to decarbonize heating, cooling, cooking, as well as all buildings and transportation networks such as railways and public transport, are rarely acknowledged in EV studies. The USDOE (2018) completely ignores electric rail in its study of U.S. electrification by 2050. The IEA (2019) does not discuss the potential future competition for electricity among sectors of economic activity—industry, electricity production, buildings, public transit, agriculture—that are also presumably going to electrify and transition to renewables. Still missing in many EV narratives is recognition that hundreds of millions of people worldwide live in areas of energy poverty and lack electricity access. How will global EV uptake, electricity, and competing global middle-class demand for air conditioning, cooking, and electronic information be met? Who will decide?

Further uncertainty includes escalated energy consumption because of the rebound effect in driving, so as solar and wind energies are scaled up, these will only supplement, and not offset, fossil fuels. Increased electrification in the next few decades might offset some future oil consumption, but most forecasts for oil, based on continued high rates of automobility, project more oil consumption in the next few decades (Greene 2017; USDOE 2019b).

The enormous resource and energy problems just outlined suggest that rather than rush to lock in, we should pause, evaluate, and compare other transition scenarios such as green mobility—cycling, public transit, walking, and compact, car-free cities. The timing for such a pause is urgent because, as described in the next section, many of the world's cities, especially in wealthy nations, might undercut more truly green mobility because EVs will compete for the same city streets and public resources.

EVs as Urban Policy

EV boosters are making claims on urban space, and EV policy is, in effect, a new urban policy. Cities are considered the natural fit for EVs because of their inherently shorter routine trip distances suitable for typical battery ranges, existing electricity capacity, and higher population density, coupled with geographic clusters of wealthier kinetic elites willing to be early adapters (Berkeley et al. 2017; USDOE 2017, 2018; U.S. Public Interest Research Group [USPIRG] 2018). Yet EV spaces—dense charging networks, modernization and expansion of existing electrical grids, and new transmission and distribution systems—will bring new conflicts over urban space.[4]

A vast new infrastructure is needed, including utility rights-of-way, transformers, substations, circuits, conduits, wires, meters, electric panels, junction boxes, and hardware and software for payment, wireless connectivity, and metering. Larger charging stations at activity centers such as office parks or shopping centers might require bigger transformers and substations and more infrastructure (Crisostomo 2019). There will also be a need for consistent, standardized regulation and compatibility between chargers and vehicles.

Virtually none of this infrastructure exists presently in any comprehensive, geographically uniform pattern, and this creates a bottleneck for EV uptake that cannot be overcome without massive government subsidy (grants, tax breaks) and without urban policies (EV mandates, charging mandates) favorable to EVs (Heywood and Mackenzie 2015; Kuby 2019). Pointedly, EVs will claim much of the same urban spaces that green mobilities such as cycle lanes, bus lanes, and pedestrianization of cities also lay claim to (Bonges and Lusk 2016). A new battle over urban space—curbs, parking, buildings, and priority use of public streets—is likely to break out between EVs and green mobility. The imminent conflict over urban space, based on previously described projections of future rates of automobility, would be accompanied by more, not fewer cars, with EVs and conventional cars overlapping for decades and more, not less, driving in cities—and especially in the densest parts of cities (Creutzig 2016).

With the rise of for-hire transportation network companies (TNCs) like Uber, e-commerce deliveries, and speculation over future AVs, urban planners are examining the street curb in detail, but EV charging is often omitted from future visions (National Association of City Transportation Officials 2017; Fehr and Technologies 2018; ITF 2018; Institute of Transportation Engineers 2018b). This is especially puzzling because EV boosters are seeking to deploy millions of publicly accessible chargers, with the curb a key opportunity. California's EV mandate calls for 250,000 mostly publicly accessible chargers by 2030, most of which will be in cities. The USDOE (2017, 2018) recommends a dense network of 1.5 million fast chargers and 10 million Level 2 chargers capable of charging 15 million EVs by 2030, also mostly in cities or along major highways.

The deployment of these chargers could substantially challenge green mobility in cities, with flashpoints over parking policies and curb policies in dense urban cores (Bonges and Lusk 2016; Frontier Group 2019; Patt et al. 2019). In the United States, where 79 percent of households have at least one off-street parking space, the rush for public curbside parking would be primarily in denser central cities, where many apartment buildings do not have off-street parking. In Europe, where 40 to 60 percent of households have at least one off-street parking space, deployment of curb charging might be more widespread (Patt et al. 2019). In California one fifth of registered vehicles are owned by apartment dwellers, one fourth are registered to urban dwellers, and one third of registered vehicles belong to renters, meaning that for mass EV uptake to manifest in cities like San Francisco and Los Angeles, parts of the public curb and other public spaces must be appropriated (Wood 2019). Boosters in California propose a subsidy to apartment landlords to install parking and charging, and the state requires that private electrical utilities figure out how to deploy chargers in apartment buildings (Sisto 2019).

Promoters of electrifying privatized car-hire schemes like Uber, which replace urban cycling and transit trips and cause more congestion, envision a radical reorganization of city curb space to deploy publicly subsidized fast charging (San Francisco County Transportation Authority 2017; Schaller Consulting 2018; International Council on Clean Transportation 2019).[5] Enthusiasts of these chauffeuring services (with eventual AVs) envision new commodified curbs, subsidized charging, free use of public bus stops, and other policies favorable to the corporate EV ride-hire system (Shaheen 2018). California has mandated that TNCs transition to zero emissions by the early 2020s, and much of this points to curb charging. EV boosters also recommend converting existing parking meters to EV charging and for municipalities and states to adopt building codes and zoning regulations requiring preferential EV parking adjacent to convenient charging (Patt et al. 2019).

Charging sprawl is an additional concern. Rather than encouraging compact cities through infill on large surface parking areas and other methods, a countervailing trend might demand preservation of parking. Large retail chains would incentivize shoppers with abundant fast charging. V2G charging also requires more parking at employment centers but also commercial centers. Demand by EV owners for residences with off-street parking should also be expected, and in 2030 the USDOE (2017) assumes that 88 percent of U.S. EVs would have a household-based charger, which means regular access to a private parking space.

The appropriation of urban space for EVs is set to intensify in the next decade. An array of convenience incentives for EVs will also challenge green mobility, including free or reduced parking fees, access to high-occupant lanes and bus lanes, exemption from congestion pricing and tolls, and other privileges that also mean more appropriation of urban space by EVs (Shaheen 2018; Hardman 2019; Patt et al. 2019; Santos and Davies 2019). In China politicians offer bundles of state-backed promotion and subsidy that include purchase subsidy and tax breaks, charging ports, as well as special privileges such as free parking, waivers on driving restrictions, and use of bus lanes (Sovacool, Abrahamse, et al. 2019).

EV advocates promote pricing that prioritizes EVs mixed with public subsidy especially in dense urban cores U.S. Public Interest Research Group (USPIRG 2018; Frontier Group 2019). New EV systems in cities include new electronic information technologies, paired with cars, that present new ways of commodifying mobility and new ways of privileging the mobility of kinetic elites. EVs (potentially coupled with AVs) are poised to be a gateway to more digital surveillance and control vis-à-vis "connected" vehicles with "smart" charging.[6] This creates opportunities for road pricing and access to charging points, replacing traditional gasoline taxes with per mile fees and access fees for EV charging. From a mobility justice perspective, demand for EV spaces and EV electricity capacity (whether renewable or nonrenewable) commodifies and privatizes access in new ways and could spike electricity prices and limit or control mobility for the kinetic underclasses—the slower moving, spatially constrained, lower income majority of the world's population.

To mitigate mobility stratification and uneven geographies of EVs, some EV boosters in the United States invoke a transportation justice framework to promote subsidy for EVs and publicly accessible charging in low-income neighborhoods (Canepa, Hardman, and Tal 2019). Low-income clusters in much of the United States experience severe pollution from the car system and lack public transit and so have poor access to employment or amenities. Low-income clusters are also car dependent and so, as with targeting kinetic elite EV uptake, subsidizing EVs for the kinetic underclass is also deemed necessary.

Setting aside that this transport justice discourse lacks scaler fluency needed for analysis of EV impacts, providing subsidy for charging infrastructure in low-income neighborhoods might be a new unintended form of gentrification. Ostensibly subsidy might be about access to jobs, but deploying charging could easily be coopted for urban boosterism and gentrification. Because many low-income households are renters and reside in multifamily housing, considerable retrofitting would be necessary, and in a privatized market-based housing system, this gets passed through to renters and raises housing costs unless there is deep, extensive government subsidy and intervention in the housing market. EVs and the installation of EV space in cities might perpetuate place making for the kinetic elite while accentuating carbon gentrification whereby working-class people are displaced and alienated from gentrifying low-carbon centers transitioning to EVs (Sheller 2018; Rice et al. 2019).

Transitioning to EVs will not help equity if the "smart city" is only made more expensive and is coopted by elites while the poor are displaced (Sheller 2018). Anable and Goodwin (2019) warned of the upper classes in the United Kingdom taking up electric SUVs and heavier luxury cars and recommended that EV SUVs and luxury cars must be strictly limited. ITF (2018a) also called for tempering EV uptake by elites because it bypasses the lower income majority and requires enormous subsidy to provide kinetic elites a device that might not help with the climate. Rather, EVs might accentuate uneven mobility such that kinetic underclasses are stuck with public disinvestment in transport infrastructure and displacement from the livable parts of cities, forced outward and compelled to drive further in inferior and more polluting (in terms of tailpipe emissions), unconnected cars. This feeds into class resentment because the lower class and working class are left with an inferior conventional car system, public disinvestment in transit, and deeper inequality and mobility stratification (Sheller 2018).

Cross-cutting inequity and class resentment, Sovacool and Axsen (2018) warned that elite uptake of EVs will likely extend the worst parts of automobility such as "cocooning" or "secession" by way of the car maintaining a privatized sanctuary and zone of protection through urban space, replicating an arms race of SUVs and other securitized practices (see also Henderson 2006). The EV (and AVs in a decade or more) would also accentuate the car as "mobile office," with connectivity to Internet, phones, and other devices making it convenient to work or multitask while stalled in traffic and even while driving. Overlaying EVs onto already high levels of car use in existing urban spaces will worsen congestion and accentuate vehicular fatalities and injury, undermining the safety and utility of cycling and walking, and ultimately discouraging the uptake of green mobilities.

Conclusion: Research Directions in Geography

There is an epochal decision about mobility in front of us, and based on recent IPCC (2018) findings, the next decade suggests that little room for error can be tolerated. Today's inflection point of potential EV lock-in is incredibly unique in that there is widespread political support to decarbonize away from fossil fuels and reduce transport emissions, yet EVs appear to be the wrong way to do it. Geographers; energy, sustainability, and transport scholars; urban planners; and other scholars and professionals should carefully scrutinize this rapid acceleration toward EVs. Three areas are ripe for deeper inquiry into EVs and the broader future of mobility: (1) Critical analysis of the assumptions of more cars in the future and inclusion of green mobility in future projections; (2) closer interrogation of the resource, emissions, and energy claims of EVs; and (3) examination of the politics of mobility of EVs.

First, as described in the first part of this article, much of the contemporary mainstream discourse over future mobility narrowly distinguishes between EVs, conventional gasoline cars, biofuels, or other propulsion and assumes more cars and more driving. This expert research conducted in academic and professional outfits limits public policy because vehicle technology and fuel sources are compared in excruciating detail, whereas green mobility scenarios are absent. The NRC (2010) acknowledged this shortcoming and called for comparative studies of future vehicles to include transit and other green mobility and not just compare different types of cars (Heywood and Mackenzie 2015; Creutzig 2016). The ITF (2018a) suggested that wealthy countries should temper their proposed EV uptake and instead focus on congestion pricing, development of compact cities, and encouraging mode shift to cycling and public transit, because these are an assured path to necessary decarbonization targets.

Research into future geographies of climate, energy, cities, and mobility should include car-free and car-lite scenarios that can provide sharp contrasts to the EV uptake scenarios and press this question: Is continued automobility desirable (Bergman, Schwanen, and Sovacool 2017)? Geographers should look to the enormous decarbonization potential from compact cities, densifying and reorganizing urban space (Ewing et al. 2008; Creutzig 2016). For example, in a case study of four European cities, 50 percent of urban GHGs could disappear with green mobility and compact city policies, and in cities worldwide a reduction of 20 to 50 percent of all urban GHG emissions is possible (Creutzig, Mühlhoff, and Römer 2012). Even in California, a world leader in EV promotion, the Air Resources Board warns that California will not meet the 2030 emissions reduction target of 40 percent of 1990 levels unless routine driving is reduced by at least 25 percent of 2018 levels (CARB 2018, 2019a). This means reconfiguring urban spaces to enable less driving and more green mobility.

Researchers can also consider how an alternative green mobility lock-in can include a very limited uptake of EVs, including electric public buses, electrification of freight including small urban delivery vehicles, and other forms of EV mobility that support rather than compete or hinder green mobility and compact cities systems. Anable and Goodwin (2019) recommended government limits on the size and use of EVs (as well as phasing out conventional gasoline cars and hybrids by 2030). They urge car-free and car-lite living, recommend car-sharing clubs instead of car ownership, and deep subsidy to green mobility modes, compact cities, and extensive roadway pricing accounting for social factors and equity (and ostensibly to raise revenue for green mobility).

Second, mobility justice requires that scholars and researchers ask whether electrification of mass automobility is truly desirable from a resource, emissions, and energy standpoint. In the extensive academic and industry literature, acknowledgment and inventorying of displaced (emissions embodied in EVs but produced somewhere else) and cumulative emissions (the sum of past emissions) is frequently absent. Projections of future energy consumption, mobility, and emissions do not account for the fact that the wealthy nations leading the uptake of EVs also disproportionately created the climate crisis. EV-oriented governments, such as those of California or Norway, might celebrate EVs as zero emissions vehicles helping to meet respective local GHG emissions targets, but failure to account for offshore production of batteries or battery disposal means that emissions are displaced globally. Cumulative emissions from the 120-year legacy of European, North American, and Oceanic automobility must be factored into and balanced against the calculations of future emissions inventories for EVs (and mobility more broadly; Banister 2011; Heede 2014). There must be transparency in the materiality of the EV. Thinking through geographic scale, researchers can map and inventory displaced and cumulative emissions more accurately. Geography can help provide a comprehensive understanding of the total emissions from EVs (or any other kind of car). For EVs the full life cycle of the charging infrastructure should be included, as well as the proportion of new renewable or low-carbon electricity capacity directed toward charging the EV system. More robust analysis of EVs (and cars in general) must go beyond the vehicles and fuels and include the infrastructure necessary for mobility, such as concrete, while also considering impacts beyond carbon emissions, such as water consumption to produce and operate the car system (Chester and Horvath 2009). New evidence on the expanding carbon footprint of the Internet and big data suggests that the portions of these infrastructures supporting EVs (and symbiosis with AVs) need to be part of the inventory as well (Belkhir and Elmeligi 2018).

Third, a mobility justice framework questions the politics of mobility behind EV promotion, and especially the politics of the kinetic elite, because it is this class that will disproportionately benefit from the EV transition. Before we can mitigate the injustices of a century of driving (and cumulative, displaced emissions) in wealthy nations, kinetic elites, including scholars and transport professionals, first need to stop disregarding involvement with them and overcome the taboos about talking about their own role in excessive consumption of acceleration, speed, and mobility (Sheller 2018).

Confronting the mobility assumptions of the kinetic elite includes decoupling ideas such as equating increased mobility with freedom and privileging speed and acceleration for the individual. Geographers' spatial predisposition can help imagine ways to decouple important values about freedom from desire for unfettered mobility. In what ways can we decouple liberal notions of freedom from car ownership, high rates of driving, air travel, and other energy-intensive mobilities dominated by the kinetic elite? This does not mean dismissing personal freedom but instead offering reconceptualization of green mobility as enhancing individual autonomy and liberty. Liberal freedom must be reimagined, emphasizing that universal access to public transport, cycling, and walking systems is also freedom. Geographers and other scholars can also show how a mobility that is firmly public, and not private, can help overcome the splintered systems that stratify mobility classes. Mobility can be reimagined as a commons-based, collective, nonindividualistic approach to movement, with mobility considered a shared public good (Nikolaeva et al. 2019). Housing and employment security are also key to a green mobility transition, and car-free decarbonized living arrangements must be available to low-income working-class people so that driving is not compelled to survive. Given the urgency of our time, the scope of future research in geography must include questioning the demand for mobility and speed, of clearly inventorying the cumulative and displaced emissions of preexisting and future automobility, along with imagining geographies that enable deep decarbonization of mobility. We do not have ten more years to spare.

Note

1. In this article I limit the scope to cars—battery electric vehicles (BEVs), which are fully electric and rechargeable, and plug-in hybrid electric vehicles (PHEVs), which contain a rechargeable battery that is also charged by conventional gasoline or biofuels. PHEVs are considered a bridge to fully electrified future BEVs powered by renewable energy but are more common now because of limited battery range, public range anxiety, and lack of ubiquitous charging systems (IEA 2019). Current battery technologies limit electrification to cars and smaller delivery vehicles, but this is currently infeasible for long-haul trucks, airplanes, and ships until a breakthrough occurs (Logan Goldie-Scot 2019). Other electric vehicles such as e-bikes and scooters might become more important to green mobility debates as well.
2. The Trump administration, in actions that seem defensive of conventional petroleum-based automobility, has controversially slowed adoption of stricter automobile emissions standards meant to help stimulate EV uptake and has not continued the EV rebate or Obama-era emissions standards.
3. California's Mountain Pass, once the world's largest REE mine, was shuttered in 2002 due to a radioactive leak into groundwater (U.S. Geological Survey 2002).
4. The hierarchy of charging includes Level 1 connections via a standard wall outlet (slow, twelve-hour charging); faster (two to eight hours), Level 2 chargers on special posts; and DCFC or fast charging towers similar in height to gasoline pumps and considered necessary for increasing EV range (USPIRG 2018).
5. Battery swapping is not foreseeable. Batteries are heavy, located at the bottom underbelly of the cars, need to be connected to cooling systems, and must be reinstalled exactly right or will degrade, rattle, and so on. Wireless charging is not yet deployed (Hove and Sandalow 2019)
6. Many EV boosters also share enthusiasm for AVs, but there are tremendous obstacles to fully driverless cars for the foreseeable future.

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