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How electric ride-hailing can support Massachusetts' 100% electric vehicle goals

Authors: Peter Slowik

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Introduction

The market for electric vehicles and ride-hailing services continues to expand worldwide. Although largely separate trends through 2021, vehicle technology advancements and private and public sector commitments indicate that ride-hailing fleets are poised to shift to electric vehicles. In the United States, the two largest ride-hailing companies, Uber and Lyft, have announced goals to transition entirely to electric vehicles by 2030.[1] At the same time, governments are setting goals to accelerate the electric vehicle market and are planning accordingly with regulatory, incentive, infrastructure, and other policies. Twelve U.S. states have adopted ZEV standards which require automakers to sell greater shares of ZEVs over time,[2] and several have announced their vision to shift entirely to 100% ZEVs over the 2035 to 2050 timeframe.[3]

Massachusetts is one such state that has set a goal for 100% of light-duty vehicle sales being electric by 2035 to mitigate the climate, public health, and economic externalities of transportation emissions.[4] As a signatory of the State Zero-Emission Vehicle Programs Memorandum of Understanding, Massachusetts is committed to deploying 300,000 ZEVs

1 "Millions of rides a day. Zero emissions." Uber, accessed December 7, 2021, https://www.uber.com/us/en/about/sustainability/ and "Leading the transition to zero emissions: our commitment to 100% electric vehicles by 2030," Lyft, June 17, 2020, https://www.lyft.com/blog/posts/leading-the-transition-to-zero-emissions

2 "Zero emission vehicles," Vermont Department of Environmental Conservation, accessed October 2020, https://dec.vermont.gov/air-quality/mobile-sources/zev

3 See for example: California Executive Order N-79-20, Governor of the State of California, September 23, 2020, https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-text.pdf and "Members," International Zero-Emission Vehicle Alliance, accessed December 2020, http://www.zevalliance.org/members/

4 "Baker-Polito Administration Releases Roadmap to Achieve Net Zero Emissions by 2050," Massachusetts Executive Office of Energy and Environmental Affairs, December 30, 2020, https://www.mass.gov/news/baker-polito-administration-releases-roadmap-to-achieve-net-zero-emissions-by-2050

www.theicct.org

communications@theicct.org

twitter @theicct

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by 2025. To do so, Massachusetts has adopted the ZEV regulation, offers substantial purchase incentives for eligible fleets and privately-owned electric vehicles, is supporting public and private charging infrastructure deployment, and participates in the Multi-State ZEV Task Force to coordinate and collaborate on ZEV market development strategies with nine other U.S. states. Ride-hailing is an important pillar in the transportation ecosystem, and the ZEV Task Force and its partners recognize the significant benefits that would result from transitioning ride-hailing fleets to electric vehicles.[5] In Massachusetts, there were more than 90 million ride-hailing trips in 2019—an increase of about 30% from 2017—and the state has established a statewide regulatory framework to oversee ride-hailing companies and their drivers.[6] More than 210,500 drivers have been approved to offer ride-hailing services in Massachusetts as of 2019.[7]

Electrification of ride-hailing fleets offers an opportunity to eliminate their tailpipe emissions. For Massachusetts, doing so would directly contribute to the goals outlined in the state's Accelerating Clean Transportation for All program by increasing access to clean transportation technologies and broadening consumer awareness.[8] Shifting ride-hailing to electric vehicles can result in relatively greater climate and public health benefits due to the high number of miles traveled by ride-hailing vehicles. Higher mileage means that ride-hailing drivers have an opportunity for greater fuel savings by switching from gasoline vehicles to hybrid and electric alternatives compared to private drivers, resulting in lower per-mile operating costs and shorter payback periods. At the same time, the need to stop to charge during shifts means that there are opportunity costs associated with driving an electric vehicle for ride-hailing.

This working paper analyzes the anticipated timing and conditions for cost-effectively electrifying ride-hailing vehicles in Massachusetts. Findings about cost parity are broadly important to help inform the types of incentive, infrastructure, and regulatory policies that would be effective for transitioning ride-hailing fleets to electric vehicles in Massachusetts, other ZEV Task Force states, and beyond. The primary analysis is based on a total cost of operation (TCO) metric for conventional, hybrid, and battery electric vehicles over the 2021–2025 timeframe and includes shifts in vehicle technology costs, improvements in vehicle efficiency, taxes, maintenance, fuel, and other cost components. The per-mile operating costs of combustion and electric vehicles are compared under a variety of use cases, including for new and used vehicles, for short-term vehicle rentals, and for electric vehicles with and without the state vehicle rebate, and for electric vehicles with and without home charging. Based on the economic findings, the paper concludes with a discussion about the opportunity for public and private sector actions to overcome barriers to electric vehicles in ride-hailing and maximizing their cost-effectiveness.

5 Jeremy Hunt and Sarah McKearnan, "Accelerating ride-hailing electrification: challenges, benefits, and options for state action," (Northeast States for Coordinated Air Use Management, December 2020), https://www.nescaum.org/documents/ride-hailing-electrification_white-paper_120220.pdf/

6 Commonwealth of Massachusetts, "2019 data report: Rideshare in Massachusetts," (2021) https://tnc.sites.digital.mass.gov/

7 "Baker-Polito Administration Files Legislation Strengthening Public Safety Requirements for Transportation Network Companies," Commonwealth of Massachusetts, July 10, 2019 https://www.mass.gov/news/baker-polito-administration-files-legislation-strengthening-public-safety-requirements-for

8 "Accelerating Clean Transportation," Massachusetts Clean Energy Center, accessed December 7, 2021, https://www.masscec.com/accelerating-clean-transportation?utm_source=MassCEC%20Program%20Launch&utm_medium=Email&utm_campaign=ACT4All&mc_cid=4bdb8c8ef3&mc_eid=2e25e54b78

Approach

This analysis follows and builds on several previous ICCT analyses to evaluate the economics of ride-hailing vehicles, with updated data inputs specific to Massachusetts. Three reference vehicle technologies within the car vehicle class are analyzed: conventional gasoline, hybrid electric, and electric vehicles with 150-mile, 200-mile, and 250-mile range. The car vehicle class is selected based on the key factors that are commonly considered for ride-hailing drivers—fuel economy and relatively affordable upfront price—as well as the most common vehicle models typically recommended in consumer guides for ride-hailing vehicle purchases.[9] The analysis incorporates shifting upfront and operating costs from 2021 to 2025 and takes vehicle and battery technology improvements into account.

Total cost of ownership components. Primary inputs include vehicle cost, taxes, maintenance, fuel, and the opportunity cost of charging. Table 1 summarizes several key assumptions and data sources used in the analysis, including for new and used vehicle costs, new and used vehicle real world efficiency, maintenance, fuel, and electricity. The overall method of analyzing to TCO of ride-hailing vehicles follows that of Pavlenko, Slowik, and Lutsey, with several important updates.[10] Our previous work analyzed a reference vehicle with utility and size specifications that approximately match models like the Nissan Sentra, Chevrolet Cruze, Nissan Leaf, and Chevrolet Bolt; updated vehicle costs and technical specifications are adapted from a 2019 ICCT vehicle cost analysis of sales-weighted technical attributes for all passenger vehicles in the United States, including model price, rated engine power, efficiency, and size.[11] From the same study, electric vehicle costs are based on bottom-up engineering cost analyses and are representative of industry average values. Fuel and electricity prices for 2021 are based on real pricing data for the first half of 2021 in Massachusetts, and future years are based on Pavlenko, Slowik, and Lutsey. Maintenance costs for all vehicle technologies are adapted from a 2021 U.S. Department of Energy comprehensive quantification of total ownership costs.[12] Although not shown in Table 1, we incorporate the state tax rate of 6.25%.

9 See for example Joel Patel "12 best cars for Lyft and Uber drivers in 2020," *U.S.News*, May 26, 2020, https://cars.usnews.com/cars-trucks/best-cars-for-uber-drivers-and-best-cars-for-lyft-drivers

10 Nikita Pavlenko, Peter Slowik, and Nic Lutsey, *When does electrifying shared mobility make economic sense?* (ICCT: Washington, DC, 2018), https://theicct.org/publications/shared-mobility-economic-sense

11 Nic Lutsey and Mike Nicholas, *Update on electric vehicle costs in the United States through 2030*, (ICCT, Washington, DC, 2019), https://theicct.org/publications/update-US-2030-electric-vehicle-cost

12 Andrew Burnham, David Gohlke, Luke Rush, Thomas Stephens, Yan Zhou, Mark A. Delucchi, Alicia Birky, Chad Hunter, Zhenhong Lin, Shiqi Ou, Fe Xie, Camron Proctor, Steven Wiryadinata, Nawei Liu, and Madhur Boloor, *Comprehensive total cost of ownership quantification for vehicles with different size classes and powertrains,* (U.S. Department of Energy, Oak Ridge Tennessee, 2021), https://publications.anl.gov/anlpubs/2021/05/167399.pdf

Table 1. Key underlying assumptions in this analysis and their data sources

Vehicle technology	Year	New vehicle cost	New vehicle real world efficiency	Used vehicle cost	Used vehicle real world efficiency	Maintenance (cents/mile)	Fuel ($/gallon)	Home charging electricity ($/kWh)	DC fast charging electricity ($/kWh)
Conventional	2021	$30,500	31 MPG	$18,100	30 MPG	10.1	$2.91	--	--
	2025	$30,900	34 MPG	$18,300	32 MPG	10.1	$3.01	--	--
Hybrid	2021	$34,250	49 MPG	$19,800	48 MPG	9.4	$2.91	--	--
	2025	$34,400	51 MPG	$19,850	50 MPG	9.4	$3.01	--	--
BEV-150	2021	$34,350	0.27 kWh/mile	$22,650	0.28 kWh/mile	6.1	--	$0.23	$0.32
	2025	$29,100	0.27 kWh/mile	$19,200	0.27 kWh/mile	6.1	--	$0.23	$0.28
BEV-200	2021	$37,000	0.28 kWh/mile	$24,400	0.29 kWh/mile	6.1	--	$0.23	$0.32
	2025	$31,000	0.28 kWh/mile	$20,250	0.28 kWh/mile	6.1	--	$0.23	$0.28
BEV-250	2021	$39,750	0.29 kWh/mile	$26,400	0.30 kWh/mile	6.1	--	$0.23	$0.32
	2025	$33,100	0.29 kWh/mile	$21,500	0.30 kWh/mile	6.1	--	$0.23	$0.28
Source		Lutsey & Nicholas	Lutsey & Nicholas	Bauer, Hsu, & Lutsey	Bauer, Hsu, & Lutsey	Burnham et al.	U.S. EIA	Eversource	EVgo

Notes: BEV refers to a battery electric vehicle. Numbers in the table are rounded and vehicle costs do not include any available incentives.

The used vehicle cost estimates from Bauer, Hsu, and Lutsey are based on a depreciation model that is informed primarily by vehicle age and odometer mileage, along with data on the original vehicle cost in the year it was purchased for the first time.[13] Used vehicle costs are assessed for vehicles that are three years old and have an odometer reading of about 40,700 miles, based on annual travel activity data from the Transportation Energy Data Book.[14] This means that the Table 1 values for used vehicle costs in 2021 and 2025 are based on model year 2018 and model year 2022 vehicles, respectively. Vehicle technology cost inputs from the 2019 ICCT cost modeling study inform the upfront vehicle cost for the year it was originally purchased or leased by the first owner. Consistent with the approach outlined in the Bauer, Hsu, and Lutsey study of used vehicles, this analysis does not assume any battery degradation or loss of range for the used vehicles that are three years and 40,700 miles old. For context, recent reports have found that battery capacity will likely decrease by less than 20% over the full lifetime of electric vehicles.[15] Fuel and electricity costs for the analysis were sourced from the U.S. Energy Information Administration, Eversource, and EVgo.[16]

13 Gordon Bauer, Chih-Wei Hsu, and Nic Lutsey, *When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption,* (ICCT, Washington, DC, 2021), https://theicct.org/publications/EV-equity-feb2021

14 Oak Ridge National Laboratory, Transportation Energy Data Book (Edition 39, April 2021), https://tedb.ornl.gov/data/

15 See for example Steve Hanley, "New data shows heat and fast-charging responsible for more battery degradation than age or mileage." *CleanTechnica*, December 16, 2019 https://cleantechnica.com/2019/12/16/new-data-shows-heat-fast-charging-responsible-for-more-battery-degradation-than-age-or-mileage/; Mark Kane, "Check out this official Tesla Model S/X battery capacity degradation chart," *InsideEVs*, June 20, 2020, https://insideevs.com/news/429818/tesla-model-s-x-battery-capacity-degradation/; and Eric Way, "Chevy Bolt EV battery health after 100,000 miles." *Torque News*, October 3, 2019, https://www.torquenews.com/8861/chevy-bolt-ev-battery-health-after-100000-miles

16 U.S. Energy Information Administration, Petroleum & Other Liquids, (U.S. Department of Energy), https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emm_epm0_pte_sma_dpg&f=m; Eversource, *2021 Summary for Eastern Massachusetts Electric Rates for Greater Boston Service Area,* https://www.eversource.com/content/docs/default-source/rates-tariffs/ema-greater-boston-rates.pdf?sfvrsn=c27ef362_50; "EVgo fast charging pricing," EVgo, accessed December 7, 2021, https://www.evgo.com/pricing/

Average 2021 market prices for representative new and used ride-hailing vehicle models are provided as context to the Table 1 values of industry average technology costs. Selected models include an electric Chevrolet Bolt, a hybrid Toyota Prius, and a conventional Toyota Camry. Market average prices are based on automotive pricing website TrueCar.com, with corroboration from other available data sources.[17] Based on data from TrueCar, the market average price for a new 2021 Chevrolet Bolt in the Boston area is $30,332, compared to $25,476 for a Toyota Prius and $24,828 for a Toyota Camry. Market prices for used vehicles are based on available inventory of model year 2018 vehicles that have an odometer reading of 30,000 miles to 40,000 miles. A used Chevrolet Bolt costs approximately $20,000, compared to about $23,500 for a used Toyota Prius and about $21,000 for a used Toyota Camry. Although market prices can vary over time and geographically, these examples demonstrate how ride-hailing drivers may have access to relatively more affordable electric and combustion vehicle models than the industry average technology cost values for new and used vehicles applied in this analysis.

In addition to the TCO analysis for new and used vehicle purchases, this work also evaluates how the weekly ride-hailing costs compare for short-term electric and combustion vehicle rentals. Doing so is important to understand the relative costs associated with diverse vehicle procurement models and driver preferences. Weekly car rentals that come with unlimited mileage are increasingly popular for ride-hailing, and there is evidence that these programs may play an important role in the transition to electric vehicles.[18] The parameters in the cost analysis of short-term vehicle rentals include the fixed costs of weekly vehicle leases and taxes, along with the variable operating costs of fueling and the opportunity cost of charging.

Miles driven per ride-hailing vehicle. The daily mileage traveled by ride-hail drivers varies significantly. This analysis is primarily focused on full-time drivers, who represent a disproportionate share of ride-hailing miles traveled, offer the greatest per-vehicle environmental benefits when electrified, and have a higher value proposition to electrify relative to part-time ride-hailing vehicles. Full-time drivers average 40,000 miles annually and represent about 6% of ride-hailing drivers and 34% of ride-hailing miles traveled.[19] It is estimated that there are about 12,500 full-time drivers in Massachusetts, based on the total number of approved ride-hailing drivers in the state.

Figure 1 shows the full-time ride-hailing vehicle daily mileage assumed in this analysis. The vertical axis shows the frequency a certain daily mileage occurs within five-mile increments and the horizontal axis shows the daily miles driven on working days. The distribution shown is adapted from Jenn and is based on travel activity data from vehicles that are used by a driver whose primary occupation is ride-hailing and is considered to be an upper-bound of ride-hailing vehicle travel activity.[20] Based on the distribution shown and the assumption that full-time drivers work 280 days per year and

17 TrueCar, accessed September 21, 2021, https://www.truecar.com/. Market average vehicle prices on TrueCar.com were assessed based on the lowest cost option available for each model. TrueCar data were corroborated with market data from other automotive websites including Kelley Blue Book and cars.com.

18 Andrew J Hawkins, "Lyft vows '100 percent' of its vehicles will be electric by 2030," *Verge*, June 17, 2020, https://www.theverge.com/2020/6/17/21294040/lyft-electric-vehicle-ev-100-percent-2030 and Lyft "The path to zero emissions: 100% electric vehicles by 2030," June 17, 2020, https://lyft-impact-assets.s3.amazonaws.com/images/path-to-zero-emissions.pdf

19 Mike Nicholas, Peter Slowik, and Nic Lutsey, *Charging infrastructure requirements to support electric ride-hailing in U.S. cities,* (ICCT: Washington, DC, 2020), https://theicct.org/publications/charging-infrastructure-electric-ride-hailing-us-032020

20 Alan Jenn, *Emissions benefits of electric vehicles in Uber and Lyft services,* (Institute of Transportation Studies: Davis, CA, 2019), https://escholarship.org/uc/item/15s1h1kn

average 40,000 miles, the average daily mileage is approximately 140 miles–145 miles per working day. About half of all working driver-days involve 95 miles–185 miles of driving, and about 12% of driver working days exceed 250 miles.

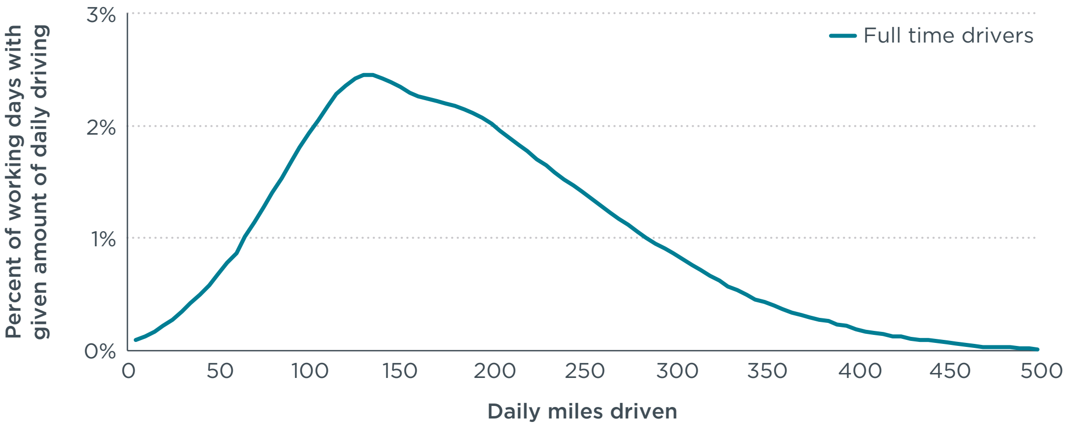

Figure 1. Assumed daily mile distributions for full-time ride-hailing drivers

The distribution of daily miles traveled informs several components of the total cost of ownership analysis. Most prominently, the variation in daily mileage informs the vehicle fueling and charging behavior, including the number of stops per day and the relative share of off-shift home or near-home Level 2 charging relative to public fast charging. The number of stops per day and share of off-shift Level 2 versus public DC fast charging are key to assessing the total energy costs and opportunity costs of charging. Consistent with our previous methodology, it is assumed that drivers will seek out DC fast charging when their remaining battery range falls below 50 miles on a given driving day. Over the course of a year, the average number of DC fast charging stops per day for a 250-mile range electric vehicle is about 0.1 for drivers with home charging and 0.9 for drivers without home charging. For combustion vehicles, the number of stops is estimated as a function of annual mileage, tank size, and fuel economy, and each refueling stop is assumed to take five minutes. The opportunity cost analysis also considers the amount of time typically required for drivers to drive to a fueling station and wait in line for it to become available and is based on data from a survey of electric ride-hailing drivers.[21]

Access to home charging for electric ride-hailing drivers. Although survey data indicate that the majority of U.S. electric ride-hailing drivers in 2019 had access to home charging, charging convenience is generally considered a greater barrier for ride-hailing drivers to switch to electric vehicles relative to the general public.[22] There are fewer charging options for drivers in multi-unit dwellings and for drivers without private garages or dedicated off-street parking. Across the state of Massachusetts, approximately 53% of the population lives in detached single-family housing, compared to 26% in attached homes and 21% in multi-unit dwellings. For this analysis, the share of population living in detached single-family homes is reduced by a third for ride-hailing drivers to reflect the types of housing in which they live, and redistributed to the remaining population in attached and multi-family housing types. Survey data of relative access to home charging is applied to the assumed housing types for ride-

21 Angela Sanguinetti and Ken Kurani, *Characteristics and experiences of ride-hailing drivers with plug-in electric vehicles,* (Institute of Transportation Studies: Davis, CA, 2020), https://escholarship.org/uc/item/1203t5fj

22 Sanguinetti and Kurani, *Characteristics and experiences of ride-hailing drivers with plug-in electric vehicles*

hailing drivers to estimate the portion with home charging access by housing type.[23] Table 2 summarizes these percentages and shows how an estimated 46% of drivers in Massachusetts could feasibly install Level 2 home charging.

Table 2. Access to Level 2 home charging by housing type for private drivers, assumed housing type for ride-hailing drivers, and implied ride-hailing driver access to home charging

	Detached home	Attached home	Multi-family housing	Total
Level 2 home charging access potential for general public	68%	49%	17%	–
Assumed housing type of ride-hailing drivers	35%	35%	30%	–
Estimated portion of ride-hailing drivers with home charging access	24%	17%	5%	46%

Electric vehicle charging time is a function of battery capacity and charging speed. An average transfer rate of 50 kW in 2020 that increases to 150 kW in 2030 is assumed. As charging speeds increase, electric vehicle charging times decrease. For drivers without off-shift home or near-home Level 2 charging (hereby referred to as "home" charging), the amount of energy transferred per charging event is calculated based on the assumption that drivers seek DC fast charging when their remaining battery range falls below 50 miles and that they remain plugged in until reaching 90% battery state-of-charge. Drivers with home charging are assumed to seek DC fast charging when their remaining battery range falls below 50 miles, and they remain plugged in only long enough to complete the daily shift before fully recharging at home. On average, the number of minutes per charging event for a 250-mile electric vehicle without home charging decreases from about 65 minutes in 2021 to about 25 minutes in 2030. Time spent charging and refueling is used to quantify the opportunity cost of time that otherwise could have been spent driving. It is assumed that the hourly earnings before vehicle expenses are $18.77, based on Boston ride-hailin driver data from the World Resources Institute.[24]

The share of miles traveled that are fueled by electricity from a home charger greatly impacts the overall energy costs and opportunity costs associated with public fast charging events. Table 3 summarizes the percent of miles supplied by electricity from home charging for electric ride-hail drivers using a battery electric vehicle (BEV) for three home charging cases: where drivers have regular access to home charging (i.e., drivers with home charging 100% of nights), drivers with some access to home charging (home charging is available 50% of nights), and drivers with no home charging who use only DC fast charging. The table shows how longer-range electric vehicles travel relatively more miles on home charging compared to shorter-range electric vehicles. Based on the distribution from Figure 1, this analysis finds that when drivers have regular access to home charging, the share of annual miles traveled on home charging ranges from 58% for the 150-mile range electric vehicle to 90% for the 250-mile range electric vehicle. When home charging is available 50% of nights, these values decrease to about 38% for the 150-mile range electric vehicle and to 63% for the 250-mile electric vehicle.

23 Gil Tal, Jae Hyun Lee, and Mike Nicholas, *Observed charging rates in California,* (Institute of Transportation Studies: Davis, CA, 2018), https://escholarship.org/uc/item/2038613r

24 Leah Lazer, Sadanand Wachche, Ryan Sclar, and Sarah Cassius, *Electrifying ride-hailing in the United States, Europe, and Canada: how to enable ride-hailing drivers to switch to electric vehicles*, (World Resources Institute, 2021), https://www.wri.org/research/electrifying-ride-hailing-united-states-europe-canada

Table 3. Percent of miles supplied by electricity from home charging for electric ride-hail drivers

Home charging access	BEV-150	BEV-200	BEV-250
Regular access (100% of nights)	58%	78%	90%
Some access (50% of nights)	38%	52%	63%
No access (0% of nights)	0%	0%	0%

Policy incentives. Policy incentives in this analysis include the Massachusetts MOR-EV $2,500 rebate for the purchase or lease of new electric vehicles. Used vehicles are not eligible for the MOR-EV rebate. The $7,500 federal income tax credit for electric vehicles is not included because it expires at different times for different automakers depending on when they reach 200,000 sales. The analysis also evaluates how taxes or fees in Massachusetts might steer ride-hailing fleets toward electric vehicles. In Massachusetts, ride-hailing companies pay a 20 cent per-ride assessment that is distributed to local jurisdictions; about $18 million was collected in 2019.[25] All trips pay the 20 cent per-ride assessment in 2021, regardless of vehicle technology. The analysis introduces a hypothetical scenario where electric vehicles are exempt from the state assessment, which we refer to as "fees." To analyze the effect of fees on the ride-hailing costs, we use data from Schaller Consulting on typical ride-hailing trip distance and deadheading (i.e., non-fare generating miles) to determine the average number of rides per vehicle per year.[26]

Results

This section summarizes the findings of the ride-hailing total cost of ownership using that approach and assumptions discussed above. The results are presented for a variety of cases, including for new, used, and leased vehicles, for electric ride-hail drivers that do and do not have access to home charging, and for a hypothetical case where electric vehicles are exempt from the Massachusetts per-ride fee. These findings help to inform the types of incentive, infrastructure, and complementary policy that would be most effective for improving the economics of electric vehicles in ride-hailing.

Total cost of ownership for new vehicles

Figure 2 illustrates the new vehicle five-year total cost of operation for full-time ride-hailing drivers in Massachusetts in 2021 for five vehicle technologies: 150-, 200- and 250-mile range electric vehicles; a 49 mile-per gallon hybrid vehicle; and a 31 mile-per gallon conventional vehicle. The stacked bars represent the five-year total cost of operation, and the black hashed line represents the average cost per mile. As shown, the average cost per mile ranges from about $0.33 to $0.37, which is approximately $13,200 to $14,800 per year. The hybrid has the lowest per-mile cost whereas the BEV-150 has the highest per-mile cost. The BEVs in Figure 2 are assumed to have access to home charging every night. The 150-mile range BEV has the highest fuel and opportunity costs of the three BEVs, as the shorter range increases the need to stop and recharge at public DC fast charging stations, resulting in more expensive electricity and greater downtime and opportunity costs. The BEV-200 and BEV-250 have comparable per-mile costs of $0.35, which is about the same as the conventional vehicle and 7% greater than the hybrid.

25 Commonwealth of Massachusetts, "2019 data report: Rideshare in Massachusetts," (2021), https://tnc.sites.digital.mass.gov/

26 Schaller Consulting, "The new automobility: Lyft, Uber and the future of American cities," (2018), http://www.schallerconsult.com/rideservices/automobility.pdf

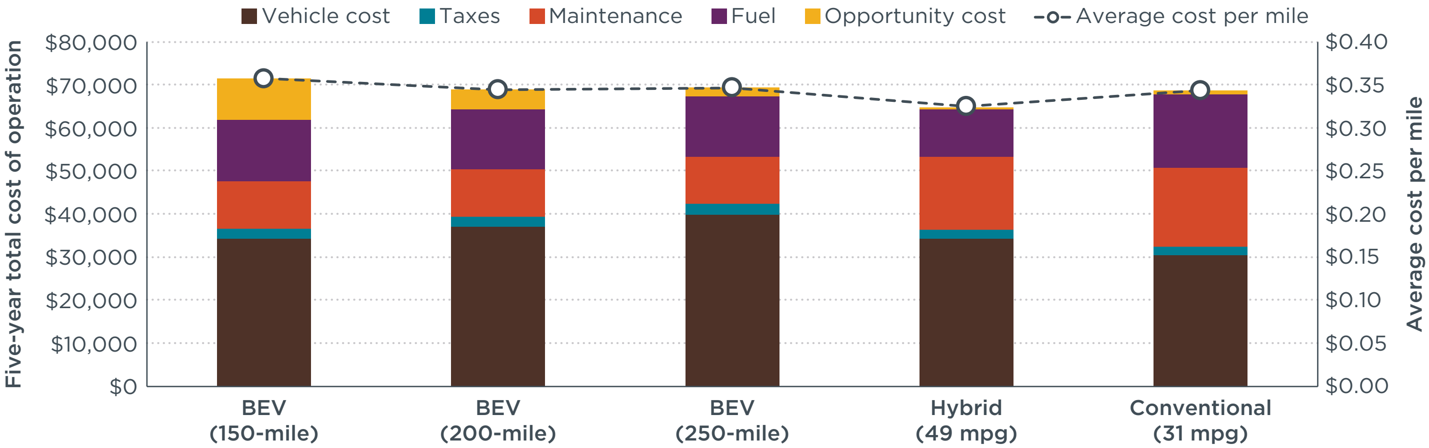

Figure 2. Comparison of new vehicle five-year TCO across vehicle technologies for full-time ride-hailing drivers in Massachusetts in 2021. All electric vehicles are assumed to have home charging.

Several additional points help to explain the findings shown in Figure 2. The higher upfront costs of electric vehicles are partially offset over time due to maintenance cost savings of over $6,000 in high mileage applications. No federal or state incentives for electric vehicles are applied in Figure 2. Applying the Massachusetts $2,500 rebate for electric vehicles would reduce the per-mile costs by about $0.01, which is not enough to achieve cost parity with the hybrid in 2021. Applying the $7,500 federal income tax credit for electric vehicles would reduce the per-mile costs to about $0.30–$0.32, making electric vehicles the lowest-cost option.

The figure also shows how electric vehicles save about $3,0000 in fuel costs over the five-year period relative to conventional vehicles. Compared to the hybrid, however, the lower fuel costs typically associated with electric vehicles is eliminated based on 2021 energy prices in Massachusetts. In 2021, a new gasoline powered hybrid car with an efficiency of 49 miles per gallon spending $2.91/gallon in Massachusetts equates to $0.06/mile in fuel costs. In comparison, a new 250-mile range electric car with an efficiency of 30 kWh/100 miles spending $0.23 per kWh at a home charger is about 15% greater than the hybrid at $0.07/mile. Electricity would have to cost less than $0.20 per kWh for charging at home to cost the same as driving a hybrid on gasoline.

For electric ride-hail drivers who do not have access to home charging and rely on DC fast charging for all of their energy needs, the five-year total cost of operation is increased by about 15% to 30%. Without home charging, driving an electric vehicle for ride-hailing is more expensive than driving comparable conventional and hybrid vehicles by about 27% and 35%, respectively. This underscores the critical need for electric ride-hail drivers to have regular access to affordable home or near-home Level 2 charging options. The value proposition for electric vehicles would be greatly improved if utility programs like time-of-use rates for residential charging or other lower-cost off-peak rates were widely available across the state.

Figure 2 does not show the state fee on ride-hailing, which is identical for all vehicle technologies: Massachusetts collects 20 cents per-ride for all trips in the commonwealth. In 2021, legislation in Massachusetts was vetoed that would have increased the state fee to 40 cents for shared trips and $1.20 for single-occupant trips.[27] At least 17 other U.S.

27 Metropolitan Area Planning Council, “TNC fees could raise over $100 million annually for MBTA, municipalities, & more.” (January 13, 2021) https://www.mapc.org/resource-library/2021-tnc-fees/

states and cities levy some sort of tax or fee on ride-hailing, and several have designed their programs to incentivize ride-hailing company and driver behavior to meet social or electrification objectives.[28] Examples include exempting or partially exempting ride-hailing trips that are in underserved areas (Chicago), pooled trips that are shared amongst multiple passengers (New York City, San Francisco), and trips in zero-emission vehicles (San Francisco).

Figure 3 shows the same new vehicle five-year TCO comparison for full-time ride-hailing drivers in Massachusetts in 2021, with the 20-cent fee shown in green, and with the state $2,500 rebate for electric vehicles applied. The figure is a hypothetical scenario where only combustion vehicles pay into the state fee; electric vehicles are exempt and the savings are passed along to drivers. The value of fees is assessed based on data on typical ride-hailing trip distance and deadheading (i.e., non-fare generating miles) to determine the number of annual trips. As shown by the green bars, the state fees sum up to more than $5,000 over a five-year period. When electric vehicles are exempt, the TCO is reduced by that amount. As shown, 200- and 250-mile range electric vehicles can achieve cost parity with similar hybrids in 2021 when they are exempt from fees and when the state rebate for electric vehicles is applied.

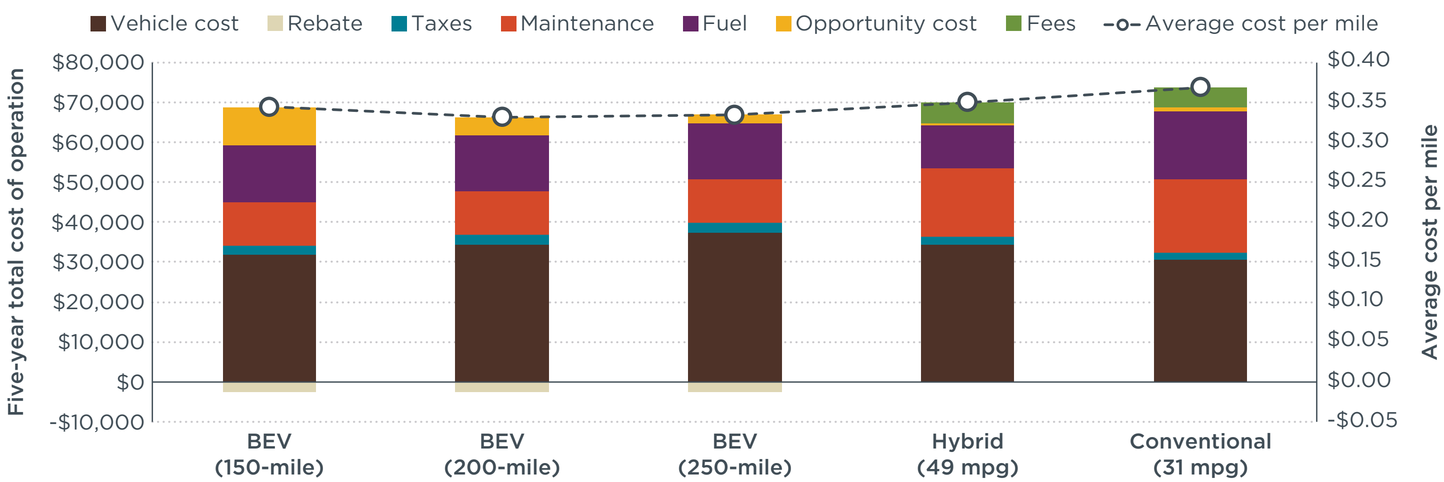

Figure 3. Comparison of new vehicle five-year TCO across vehicle technologies for full-time ride-hailing drivers in Massachusetts in 2021 with fees. All electric vehicles are assumed to have home charging.

As above, the five-year TCO for electric ride-hail drivers who do not have home charging is increased by about 15% to 30%. Without home charging, electric vehicles have higher per-mile costs than the comparable hybrid and conventional vehicles. If electric vehicles are exempt from fees, a per-trip fee of about $1.10 is sufficient for electric vehicle without home charging to have a lower five-year TCO than hybrid vehicles in Massachusetts. For context, this fee value approximately matches the $1.20 fee for single-occupant trips that was proposed in Massachusetts in 2021, although the legislation did not include exemptions for electric vehicles.

As vehicle technologies continue to improve and energy costs shift overtime, the relative costs incurred by ride-hailing drivers evolve for different vehicle technologies. Most prominently, substantial electric vehicle cost reductions are expected to continue

28 Peter Slowik, Sandra Wappelhorst, and Nic Lutsey. *How can taxes and fees on ride-hailing fleets steer them to electrify?* (ICCT: Washington, DC, 2019). https://theicct.org/publications/taxes-and-fees-electrify-ridehailing

through 2025, along with small increases in combustion vehicle costs to comply with emissions regulations. Vehicle efficiency are assumed to continue to improve incrementally for each of the vehicle technologies, and modest changes are projected for gasoline and electricity prices. Table 1 above summarizes the evolution of vehicle technology and energy costs applied in this analysis.

Figure 4 illustrates the new vehicle five-year TCO for the five vehicle technologies in 2025. For the electric vehicles, results are shown, from left to right, for cases where drivers have regular access to home charging (i.e., drivers with home charging 100% of nights), drivers with some access to home charging (home charging is available 50% of nights), and drivers with no home charging who use only DC fast charging. The figure shows how electric vehicles have the lowest per-mile cost when drivers have regular access to home charging. Relative to 250-mile electric vehicles, 150-mile electric vehicle have lower upfront vehicle cost but higher fuel and opportunity costs due to the greater need to stop and recharge at DC fast chargers. The conventional and hybrid vehicles have per-mile costs of $0.34 and $0.32, respectively. By 2025, electric vehicles with regular home charging have the lowest per-mile costs at $0.30 to $0.31 (equivalent to about $12,000 to $12,500 per year), while electric vehicles with some home charging are cost-competitive with hybrids. Without home charging, electric vehicles remain the most expensive technology through 2025. No state or federal electric vehicle purchase incentives are included in the 2025 TCO analysis.

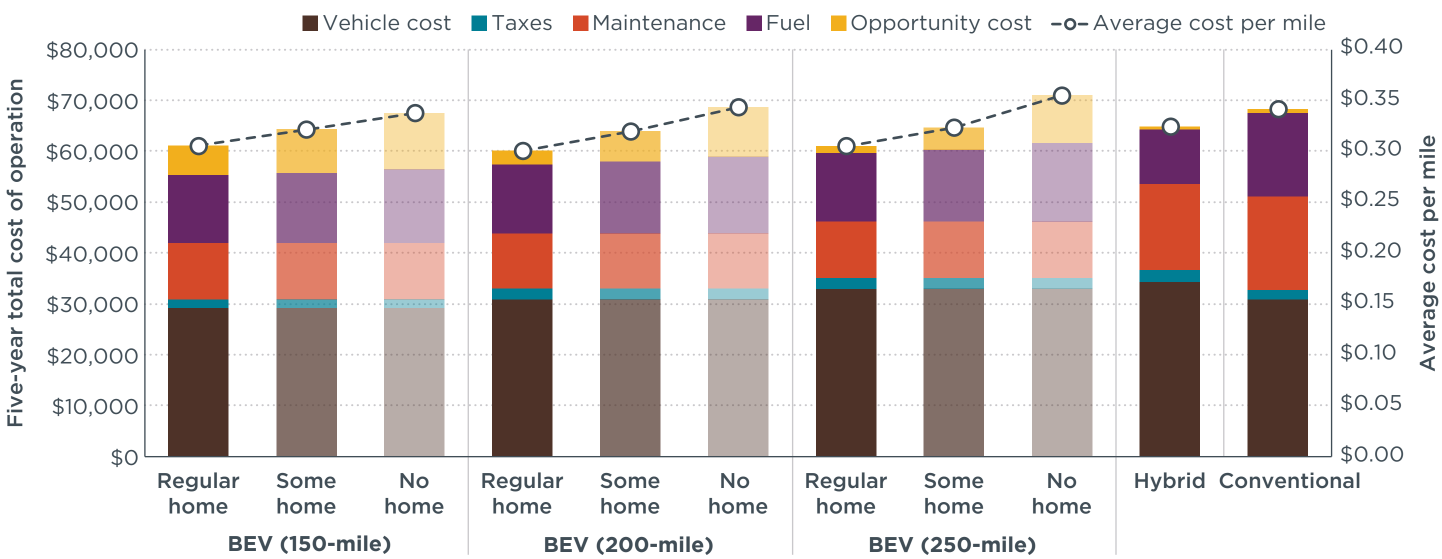

Figure 4. Comparison of new vehicle five-year TCO across vehicle technologies for full-time ride-hailing drivers in Massachusetts in 2025

Several additional points help to put the Figure 4 findings in context. Based on survey data, electric ride-hailing drivers charge most often at home.[29] On average, electric ride-hail drivers charge at home 58% of the time, followed by at public (36%) and workplace chargers (6%). Of ride-hailing drivers, 23% never charge at home, of which 54% were unable to, 39% chose not to, and 7% did not know if they could. Of electric ride-hailing drivers who could charge at home but choose not to, some may participate in a free or discounted DC fast charging program while others have access to convenient and affordable overnight Level 2 charging, or free or discounted charging at work.

29 Sanguinetti and Kurani, *Characteristics and experiences of ride-hailing drivers with plug-in electric vehicles*

Because this analysis estimates that about 46% of all ride-hail drivers in Massachusetts could feasibly install Level 2 home charging, greater efforts to increase access to regular home and near-home affordable Level 2 chargers are needed for all drivers to access the economic benefits of electric vehicles.

Total cost of ownership for used vehicles

The used electric vehicle market offers great potential for expanding electric vehicle access to lower-income households by increasing electric vehicle affordability. Previous analysis of privately-owned vehicles found that electric vehicles' higher rates of depreciation for first owners will lead to larger economic benefits for lower-income second owners.[30] Figure 5 illustrates the change in per-mile costs for used ride-hailing vehicles from 2021 to 2025 based on the same five-year TCO metric applied above. Used vehicle costs are assessed for vehicles that are three years old and have an odometer reading of about 40,700 miles. From 2021 to 2025, the cost of driving hybrids and conventional vehicles remains about the same, at about $0.25 per-mile and $0.28 per-mile, respectively, due to the conflicting trends of increasing gasoline prices, increasing vehicle technology costs, and lower fuel consumption due to efficiency improvements. For electric vehicles, the per-mile costs decline by about 14%, driven by reductions in vehicle and battery costs, incremental energy efficiency improvements, and lower opportunity costs from faster charging speeds. Figure 5 shows how all three of the used electric vehicles have lower per-mile costs than comparable used conventional vehicles by 2023, and that the gap continues to widen over time. Used electric vehicles with 200- and 250-mile ranges become cost competitive with comparable used hybrid vehicles in ride-hailing by 2025.

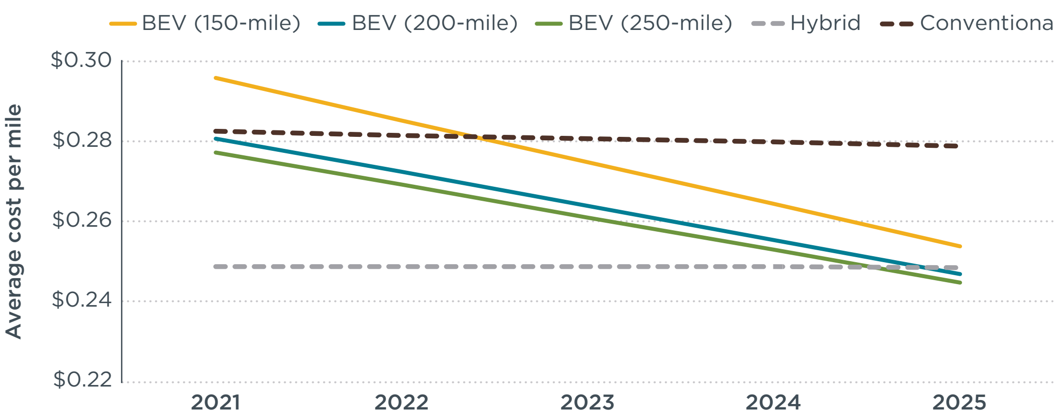

Figure 5. Comparison of used vehicle five-year TCO across vehicle technologies for full-time ride-hailing drivers in Massachusetts, 2021 to 2025. All electric vehicles are assumed to have home charging.

Several additional points provide context to the used vehicle TCO for Massachusetts ride-hailing drivers in Figure 5, which is analyzed for electric vehicle drivers with regular access to home charging. Like the findings above for new vehicles, regular access to home charging is critical for used electric vehicles to achieve cost parity with hybrids. When home charging is only available 50% of nights, the per-mile costs increase by about 10%, and by 2025 electric vehicles surpass cost parity with the conventional vehicle and remain more expensive than hybrid. Without home charging, electric

30 Gordon Bauer et al. *When might lower-income drivers benefit from electric vehicles?*

vehicles are more expensive than conventional and hybrid vehicles until after 2025. Used electric vehicles are not eligible for the Massachusetts $2,500 MOR-EV rebate. If the state rebate was expanded to include used vehicles, used electric vehicles in ride-hailing would achieve cost parity with used hybrids about one to two years faster, by 2023 for a BEV-200 and BEV-250 and by 2025 for the BEV-150. If additional rebates were available for low-income drivers, used electric vehicles would become cost-competitive with hybrids by 2022.

Total costs for weekly vehicle rentals

Ride-hailing companies and their partners are increasingly offering short-term car leases so that drivers who need a car can rent one on a weekly basis. Such programs have great potential to lower electric vehicle use barriers: short-term rentals carry inherently lower financial risk than vehicle purchases, do not require multi-year leasing contracts or significant upfront capital, and some have free DC fast charging included in their pricing. Short-term rental programs for ride-hailing drivers typically come with insurance, basic maintenance, and unlimited mileage, thereby providing motivation for drivers to drive a lot of miles. These programs may play an important role in the transition to all electric ride-hailing; Lyft, for example, expects to electrify its entire rental partner vehicle fleet sooner than drivers will shift to electric personal vehicles due to rental vehicles' greater usage and faster payback period.[31]

Vehicle availability and pricing varies substantially by program and location. Uber's major weekly vehicle rental partners include Avis, Hertz, and Kinto, and Lyft's major weekly vehicle rental partners through its Express Drive program include Flexdrive and Hertz.[32] Electric vehicles do not appear to be available on any of the major ride-hailing company vehicle rental partner platforms in Massachusetts, indicating that access to electric vehicles is a key barrier for ride-hailing drivers in the state.[33] Uber's online vehicle marketplace portal provides pricing information for other markets.[34] In Los Angeles for example, the weekly rate for electric vehicle models like the Chevrolet Bolt or similar is about $100 greater than conventional models like the Toyota Corolla.

Figure 6 illustrates the total weekly costs of renting electric and combustion vehicles and driving full-time (i.e., about 770 miles per week, equivalent to 40,000 miles per year) in Massachusetts. Fixed costs include the vehicle leasing price and taxes and are based on pricing information from Uber's online vehicle marketplace as of August 2021. Variable operating costs include fuel and the opportunity cost of charging. The cost analysis does not include maintenance costs because basic maintenance is typically included in short-term ride-hailing vehicle rentals. From left to right, the figure shows the weekly costs for three electric vehicle cases, a hybrid vehicle, and a conventional vehicle. Electric vehicle costs are shown for three cases: no home charging, home charging, and home charging combined with a hypothetical exemption from electric vehicle rental taxes and surcharges. As shown, the hybrid vehicle and the conventional vehicle have the lowest weekly costs, at about $325. In comparison, the weekly electric vehicle costs

31 "The path to zero emissions: 100% electric vehicles by 2030," Lyft, June 17, 2020, https://lyft-impact-assets.s3.amazonaws.com/images/path-to-zero-emissions.pdf

32 Weekly rentals as low as $260/week," Uber, accessed August 5th, 2021, https://www.uber.com/us/en/drive/vehicle-solutions/ and "Express drive overview," Lyft, accessed August 5th, 2021, https://help.lyft.com/hc/e/articles/115013080108-Express-Drive-overview

33 Based on phone communication with rental partners and additional web-based research as of August 8th, 2021.

34 "Vehicle marketplace," Uber, accessed August 5th, 2021, https://bonjour.uber.com/marketplace/marketplaces/vehicles_us/weekly_rentals

are greater than the combustion models by about $25 (when exempt from rental taxes and when home charging is available) to $160 (with no home charging available).

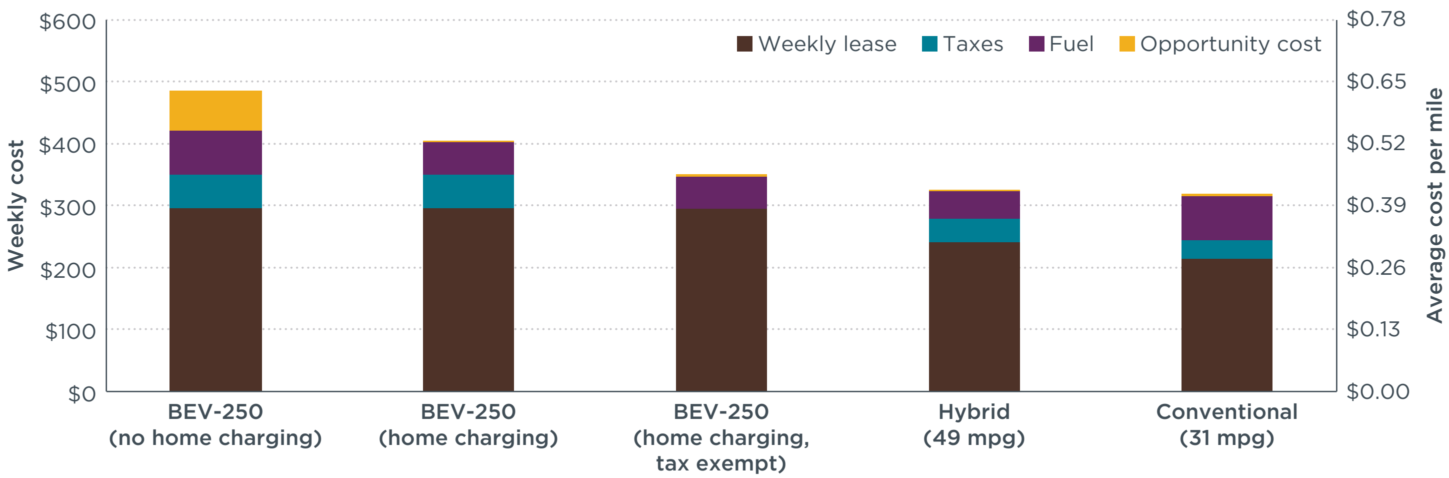

Figure 6. Weekly costs for leasing electric and combustion vehicles for ride-hailing in 2021

Several additional points help to explain the findings in Figure 6. Although electric vehicles' greater weekly costs are primarily due to higher upfront fixed costs, the hybrid has the lowest operating costs based on underlying energy prices in Massachusetts and the opportunity cost associated with charging electric vehicles away from home. This means that electric vehicles would need to have a lower fixed cost relative to combustion vehicles to achieve cost parity. In cases where drivers do not have home charging, the fixed weekly cost of electric vehicles must be at least $90 cheaper than the hybrid and $65 cheaper than the conventional model for the total costs to be identical. In cases where drivers have home charging, the fixed weekly cost of electric vehicles must be at least $10 cheaper than the hybrid for the total costs to be identical. In the case where electric vehicles are hypothetically exempt from rental taxes, the weekly fixed costs are reduced by about $55 but remain greater than the fixed costs of hybrid and conventional vehicles.

Short-term weekly ride-hailing car rentals that come with unlimited mileage are several times more expensive than typical 36-month leases. Based on pricing information from August 2021, car rental company Avis offers unlimited mile leases for a Toyota Corolla or similar models in Boston for about $305 per week.[35] In comparison, the average monthly leasing price in Boston for a 12,000 mile 36-month leased Toyota Corolla with 10% down was about $295 as of August 2021.[36] Because typical automaker leases apply additional fees for miles driven beyond the typical 12,000 mileage cap, leasing is an impractical option for full-time ride-hailing drivers but may be suitable for part-time drivers. As of mid-2021, the average monthly price for a typical 36-month lease is about $265 for a Chevrolet Bolt in the Boston area, $30 less than the Corolla. The average monthly lease price for the most affordable conventional models like the Hyundai Accent, Hyundai Elantra, Hyundai Sonata, Kia Forte, and Nissan Sentra is about $260 to $290.[37] Based on these leasing prices, the electric Chevrolet Bolt would have the lowest total per-mile costs if home charging were available to part-time ride-hail drivers.

35 "Need a vehicle to drive for Uber?" Avis, accessed August 5th, 2021, https://www.avis.com/en/uber

36 "Toyota 2022 Corolla LE," Toyota, accessed August 11th, 2021, https://smartpath.toyota.com/inventory/details?dealerCd=38029&vin=JTDEPMAE7NJ203892&source=t1&zipcode=02917

37 Auto Leasing Boston "Lease a car online in Boston" (accessed August 11th, 2021) https://autoleasingboston.com/

Discussion

Electrification of ride-hailing fleets holds great potential to eliminate vehicle tailpipe emissions from a growing industry, increase public awareness and education about electric vehicles, and broaden zero-emission mobility equity and access. However, this analysis illustrates the challenging economics for electric ride-hailing in Massachusetts in 2021, largely due to electric vehicles' greater upfront costs and high energy and opportunity costs associated with public fast charging. Based on the analysis of the timing and conditions under which electric vehicles make economic sense in Massachusetts, this section summarizes the major opportunities for policy, utility, and company actions to improve the value proposition and accelerate the transition.

The Massachusetts MOR-EV $2,500 rebate program for electric vehicles helps to partially offset the greater upfront costs of electric vehicles in 2021. In June 2020, Massachusetts expanded rebate eligibility to commercial fleets—including rental car companies—for a maximum of 25 electric vehicles. To expand electric vehicle access and equity, Massachusetts could join states like California, Connecticut, Oregon, and Pennsylvania and issue increased rebates for low- and moderate-income residents. Based on a survey of Uber drivers, more than half of drivers report household incomes below $60,000.[38] The state could also develop pilot programs to support the used electric vehicle market, such as fair financing or used vehicle incentives that target high-mileage applications, low-income communities, and areas with poor air quality.[39] At the same time, ride-hailing companies can expand upon their early incentive programs; Uber for example operated a Zero Emissions incentive program for one year that allowed drivers in the United States and Canada to earn an extra $1 per trip, up to a maximum of $4,000 per year.[40]

Access to affordable overnight charging is a key factor to electric vehicles' value proposition, and policies and programs that expand home charging access can unlock the economic benefits to drivers. Critically, the cost of driving an electric vehicle on electricity is about the same as driving a hybrid on gasoline in Massachusetts, based on 2021 electricity and gasoline prices. As utilities and Massachusetts regulators plan for electric vehicle and infrastructure investments,[41] ensuring that drivers have access to off-peak demand residential electricity that costs less than $0.20 per kWh will be key to unlocking the economic benefits of electric vehicles. At the same time, state or utility incentives for residential chargers at single-family homes and multi-unit dwellings can support the early market. Streamlined permitting and "Right to Charge" policies are important complements to incentive programs and can increase program effectiveness, access, and participation.[42] Longer-term, policies like EV-ready building codes can ensure continuing provision of charging at a lower cost. For drivers in dense

38 Beneson Strategy Group, "App-Based Driver Survey," (2020) https://ac32b1ba-8f5b-411f-91ab-b7ae9a046606.usrfiles.com/ugd/ac32b1_63f0f776a70a4cc5b532f4521ebab453.pdf

39 See for example Barrett Brown, Fair financing pilot program: Helping rideshare drivers electrify their rides," *Forth*, September 30, 2020, https://forthmobility.org/news/fair-financing-pilot-program-supporting-drivers-electrify-their-rideshare and Alexander Tankou, Nic Lutsey, and Dale Hall. *Understanding and supporting the used zero-emission vehicle market,* (ICCT: Washington, DC, 2021), https://theicct.org/publications/used-zero-emission-zeva-dec21

40 "Together on the road to zero emissions," Uber, accessed August 5th, 2021, https://www.uber.com/us/en/drive/services/electric/

41 Sarah Shemkus, "Massachusetts utilities propose plans to ramp up electric vehicle infrastructure" *Energy News Network,* September 21, 2021, https://energynews.us/2021/09/21/massachusetts-utilities-propose-plans-to-ramp-up-electric-vehicle-infrastructure/

42 See for example, California AB-970 Planning and zoning: electric vehicle charging stations: permit application: approval. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB970 and Northeast States for Coordinated Air Use Management (NESCAUM), "Right to Charge Laws," (October 2019), https://www.nescaum.org/documents/ev-right-to-charge.pdf/

metropolitan areas for whom home charging is not feasible, more inclusive and equitable deployment of low-cost near-home charging options such as curbside or streetlight sites would ideally be pursued.

Figure 1 and Table 3 show how full-time electric vehicle drivers with regular access to home charging still rely on DC fast charging for some of their energy needs, indicating that broad investments in public DC fast charging are also needed to support an expanding market. The analysis also shows how the cost of charging at DC fast chargers can exceed the per-mile cost of driving a combustion vehicle in Massachusetts. Government, utility, or private sector discounted public charging programs are needed for driving on electricity to be cheaper than driving on gasoline for everyone in Massachusetts. Such programs can simultaneously encourage greater utilization that can be complementary to private electric vehicle drivers in terms of charging times.[43] Redesigning electricity tariffs and rate structures will be key to enabling more cost-effective fast charging.[44]

Sustained funding of incentives is critical to address electric vehicle barriers and grow the market. While the total benefits of transitioning to electric vehicles far outweigh the total costs, how to optimally fund the transition remains a key question in many markets.[45] In Massachusetts, about two-thirds of the state's $75 million from the Volkswagen Settlement allocation remains.[46] The state could consider using a portion of these funds in the near-term to increase rebates for low- and moderate-income households, expand incentive eligibility for ride-hailing fleets, develop pilot programs for used electric ride-hailing vehicles, or develop grant programs for home, near-home level 2, and urban DC fast charging. While not analyzed here, typical installation and hardware costs for Level 2 home chargers in the United States range from about $680 to $4,100 depending on the electric vehicle home charging situation and housing type.[47]

As cost parity for new and used electric vehicles is reached around the 2024–2028 timeframe, governments can phase down incentive programs.[48] At the same time, shifting to durable systems of pollution-indexed fees and taxation can be a sustainable approach to incentivizing electric vehicles over the longer-term. Massachusetts collects 20 cents per-ride for all ride-hailing trips in the commonwealth, which sum up to about $1,000 per year for full-time drivers. In the near term, the state could begin exempting electric vehicles and applying higher fees for higher-polluting combustion vehicles to incentivize electric ride-hailing vehicles in a fiscally durable and revenue neutral way.[49] Continuous investments will be needed for charging infrastructure growth, and these costs can shift to market-led investments and utility ratepayer-funded deployment. Public-private partnerships will be key to identifying gaps that governments,

43 Dale Hall, Mike Nicholas, and Marie Rajon Bernard. *Guide to electrifying ride-hailing vehicles for cities,* (ICCT: Washington, DC, 2021), https://theicct.org/publications/ride-hailing-cities-guide-mar2021

44 Ross McLane, Edward J. Klock-McCook, Shenshen Li, John Schroeder. *What we learned from 100 million miles of ridehailing data.* (Rocky Mountain Institute, 2021), https://rmi.org/what-we-learned-from-100-million-miles-of-ridehailing-data/

45 Peter Slowik, Dale Hall, Nic Lutsey, Michael Nicholas, and Sandra Wappelhorst, *Funding the transition to all zero-emission vehicles,* (ICCT: Washington, DC, 2019), https://theicct.org/publications/funding-ZEV-transition

46 Connor Smith "Nearly 80 percent of VW funds remain two years after the first awards" (Atlas EV Hub, July 10, 2020) https://www.atlasevhub.com/data_story/nearly-80-percent-of-vw-funds-remain-two-years-after-the-first-awards/

47 Mike Nicholas, *Estimating electric vehicle charging infrastructure costs across major U.S. metropolitan areas*, (ICCT: Washington, DC, 2019), https://theicct.org/publication/estimating-electric-vehicle-charging-infrastructure-costs-across-major-u-s-metropolitan-areas/

48 Nic Lutsey and Mike Nicholas, *Update on electric vehicle costs in the United States through 2030;* Gordon Bauer et al. *When might lower-income drivers benefit from electric vehicles?*

49 Peter Slowik et al. *How can taxes and fees on ride-hailing fleets steer them to electrify?*

automakers, infrastructure providers, and other stakeholders can fill. At the local level, congestion charges and low-emission zones can be powerful tools for incentivizing electric vehicle uptake among ride-hailing drivers and the general public.[50]

Previous analysis of global electric ride-hailing developments reveals how company goals and actions vary greatly across the companies and regions, largely driven by local and regional policies.[51] Company electric vehicle actions broadly include public commitments, partnerships for electric vehicle supply, financial incentives, charging infrastructure investments, awareness and education activities, and pilot programs. Ensuring that the right electric vehicle models are available to drivers in sufficient volumes is a critical precursor to greater electric vehicle deployment in ride-hailing services. Access to electric vehicles is a major barrier for ride-hailing drivers in Massachusetts; electric vehicle models are not available on any of the major ride-hailing company vehicle rental partner platforms in the state as of mid-2021. The recent Hertz-Uber partnership to add up to 50,000 Teslas by 2023 for Uber drivers to rent in selected markets appears well-suited to expand electric vehicle access, and such programs would ideally be expanded to all markets and all ride-hailing companies.[52]

Elsewhere, ride-hailing companies and their partners are actively deploying electric vehicles in markets with supporting policies. In California, where the Clean Miles Standard regulation requires ride-hailing companies to shift to electric vehicles, electric vehicle rentals are available on company partner platforms with Avis, Hive, Flux, Ample, and Flexdrive.[53] In Colorado, where ride-hailing company rental programs qualify for the $4,000 electric vehicle state tax credit in 2020 and $2,500 from 2021 to 2023, Lyft has introduced hundreds of electric vehicles through its Express Drive program in the Denver area, and DC fast charging is included in the vehicle rental cost.[54] In London, where there are emissions standards for private hire vehicles and access policies that apply steep fees on polluting vehicles for accessing the city center, Uber operates a Clean Air Plan that provides drivers with financial incentives to switch to electric vehicles, and the company partners with automakers and rental car companies to provide electric vehicle financing and weekly rentals.[55] These examples demonstrate how regulatory and fiscal policies are key drivers for increased company electric vehicle actions and greater electric vehicle access for ride-hailing drivers.

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50 Hall et al. (2021) *Guide to electrifying ride-hailing vehicles for cities*

51 Peter Slowik, Lina Fedirko, and Nic Lutsey, *Assessing ride-hailing company commitments to electrification,* (ICCT: Washington, DC, 2019), https://theicct.org/publications/ridehailing-electrification-commitment

52 "Hertz partners with Uber to add up to 50,000 Teslas to Uber network by 2023," Hertz, October 27, 2021, https://newsroom.hertz.com/news-releases/news-release-details/hertz-partners-uber-add-50000-teslas-uber-network-2023

53 See for example: "Vehicle marketplace," Uber, accessed August 5th, 2021, https://bonjour.uber.com/marketplace/marketplaces/vehicles_us/weekly_rentals; "Together on the road to zero emissions," Uber, accessed August 5th, 2021, https://www.uber.com/us/en/drive/services/electric/; and Tina Bellon "Lyft launches EV rental pilot program for ride-hail drivers in Northern California," *Reuters*, June 15, 2021, https://www.reuters.com/business/autos-transportation/lyft-launches-ev-rental-pilot-program-ride-hail-drivers-northern-california-2021-06-15/

54 Lyft, "Leading the transition to zero emissions," June 17, 2020, https://www.lyft.com/blog/posts/leading-the-transition-to-zero-emissions and "Electrify America and Lyft collaborate on electric vehicle rideshare charging to help decrease emissions by increase miles traveled by EVs," Electrify America, November 19, 2019, https://media.electrifyamerica.com/en-us/releases/85

55 "Upgrading to an electric vehicle," Uber, accessed August 5th, 2021, https://www.uber.com/gb/en/u/drive-journey-to-electric/#cleanairplan and "EV upgrades and vehicle offers in London," Uber, accessed August 5th, 2021, https://www.uber-vs.com/gb/en/locations/london/

Conclusions

The global transition to electric vehicles is underway, yet the electrification of ride-hailing has been comparatively limited. This analysis investigates the timing and conditions under which electric ride-hailing makes economic sense, and the findings reveal the types of incentive, infrastructure, and regulatory policies that would be effective in overcoming barriers to electric ride-hailing in Massachusetts, ZEV Task Force States, and beyond. While the case for electrification can already be made in many situations in 2021, the analysis is focused on broader trends for typical full-time drivers. The analysis leads to the following conclusions and policy recommendations:

Based on underlying economics, electric vehicles can become the most cost-effective technology for ride-hailing drivers in Massachusetts in 2023–2025. Because of their high miles traveled, full-time ride-hailing drivers accrue greater relative fuel savings and see shorter payback periods when they switch to more fuel-efficient vehicles. Hybrids have the lowest total cost of operation in 2021 and retain that economic advantage until 2023 for new vehicles and 2025 for used vehicles in cases where electric vehicles have home charging. This trend is primarily driven by the expected continued decline in battery pack costs, along with reduced opportunity costs driven by technological advancements in fast charging speeds. In 2021, electric vehicles can be the lowest-cost technology provided that both state and federal incentives are included and home charging is available.

Ride-hailing can be at the forefront of the transition to electric vehicles in Massachusetts. The economic findings indicate that some full-time drivers can justify switching to an electric vehicle in 2023, followed by a much larger fraction of drivers by 2024–2025, and the entire fleet before 2030. Full-time drivers using personally-owned vehicles and short-term rental vehicles have the greatest value proposition for transitioning to electric before 2025, provided that home charging is available and the weekly rental costs are $25 cheaper than hybrid alternatives. Based on the number of approved drivers for ride-hailing in Massachusetts, about 12,500 full-time drivers could cost-effectively switch to electric vehicles in the 2023–2025 timeframe. For context, this is about 50% greater than the total number of electric vehicles sold in the state in 2020. The remaining 200,000 part-time drivers can economically rationalize switching to a new or used electric vehicle in the 2024–2029 timeframe based on upfront cost parity alone. This is about five times the number of electric vehicles sold in Massachusetts from 2011 through 2020.

Convenient and affordable home and near-home Level 2 charging will be essential. The electric vehicle value proposition is contingent on access to affordable charging. When home charging is not available, electric vehicles lose their 2023–2025 cost advantage due to higher energy and opportunity costs from public fast charging. Without home charging, the electric vehicles ownership costs increase by about 15% to 30%. For energy costs alone, driving an electric vehicle on home charging can be 15% more expensive than driving a hybrid on gasoline in 2021, and 60% more expensive when driving on electricity from a public fast charger. Electricity would have to cost less than $0.20 per kilowatt-hour for driving on electricity to cost the same as driving on gasoline. For drivers that rent a car on a weekly basis, this means that electric vehicles are only cost competitive with hybrids when they are $25 cheaper to rent and when home charging is available. Because more than half of ride-hail drivers are expected to be unable to feasibly install or use a Level 2 home charger, greater efforts to expand access to affordable and conveniently placed overnight charging at homes, multi-unit dwellings, curbs, and at public locations are needed.

Despite electric vehicles' promising economics, public and private sector actions are needed to ensure a complete transition. As of 2021, electric ride-hailing is primarily limited to city-specific programs that are largely driven by local and regional policies. Even when the value proposition for electric vehicles becomes clear, without supporting policy and company investments, the barriers of charging infrastructure, awareness and education, and electric vehicle model availability may slow widespread adoption. The supply of electric vehicles for ride-hailing appears especially limited in Massachusetts; electric vehicles are not available on the major ride-hailing company vehicle rental partner platforms as of 2021. Developments in California, Colorado, and London demonstrate how markets with strong regulatory, fiscal, and infrastructure policy supports tend to have the greatest electric vehicle model availability and relatively more innovative ride-hailing company programs to ensure drivers have access to electric vehicles.

Figure 7 summarizes several of the conclusions above and the key results of this work. Based on the anticipated timing that electric vehicles reach cost parity with conventional vehicles and ride-hailing company goals for a 100% zero emission fleet, the figure illustrates the share of ride-hailing electric miles traveled for full-time drivers (blue), part-time drivers (yellow) and all drivers combined (green). As depicted, the share of electric miles traveled for full-time drivers increases to more than 60% during the 2023–2025 timeframe as cost parity is reached. For part-time drivers, the share of electric miles increases incrementally through 2023 until it accelerates from about 20% to 75% in the 2024–2029 timeframe, consistent with the findings for new and used vehicle upfront cost parity identified above.

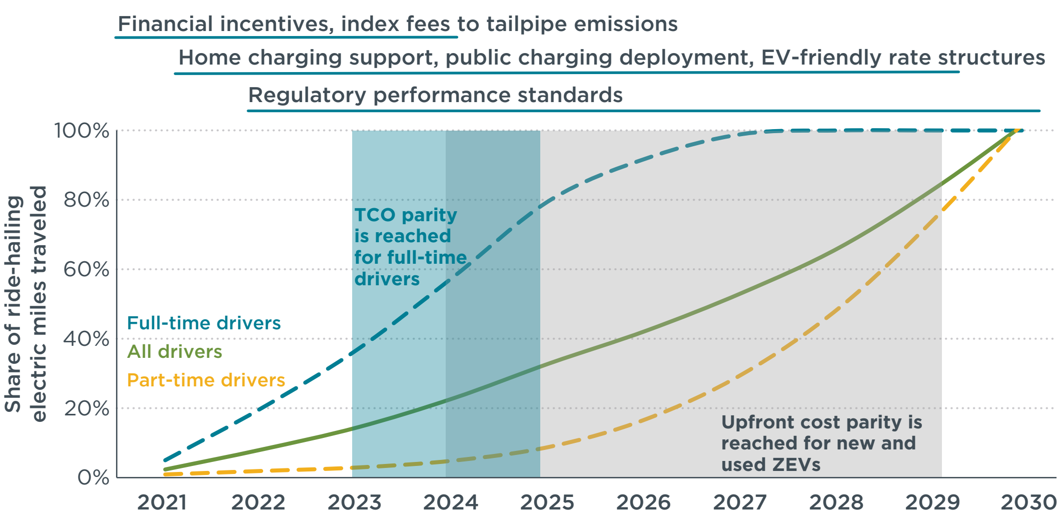

Figure 7. Percent of ride-hailing electric miles traveled and evolution of supporting policy

The evolution of policy support is plotted along the top of the figure. As shown, financial incentives and pollution-indexed pricing measures in the near-term help to offset electric vehicles' higher initial costs. Persistent and broad investments in home, near-home Level 2, and public fast charging will be needed, along with reformed electricity rate structures that enable driving on electricity to be cheaper than driving on gasoline. Over the longer-term, regulatory performance standards will be critical to bring electric vehicles to the mass market and ensure that government and company electrification goals are met.

The analytical findings and associated policy recommendations in this work are broadly aligned with the proposals and recommendations developed by the Metropolitan Area Planning Council in August 2021 as part of the Massachusetts Ride for Hire Electrification Working Group.[56] As various incentive, infrastructure, and awareness programs are developed, better data and resolution into diverse ride-hailing activities would help reveal the opportunities for targeted actions and pilot programs to overcome electrification barriers and support infrastructure planning. More broadly, California's Clean Miles Standard 2018 base-year emissions inventory report is a good example of the data and metrics required to evaluate the environmental pollution associated with ride-hailing.[57] While this analysis was conducted with regional inputs specific to Massachusetts, the findings are broadly applicable to many U.S. and global markets. Similar analyses could be conducted with updated regional data to evaluate in more detail when electric ride-hailing makes economic sense in other markets.

56 Metropolitan Area Planning Council on behalf of the Massachusetts Executive Office of Energy and Environmental Affairs, "Massachusetts Ride for Hire Electrification Working Group, Final Policy Brief" (May 2021), https://www.mapc.org/resource-library/ride4hireelectric/

57 See for example, California Air Resources Board, "2018 Base-year emissions inventory report" (2019), https://ww2.arb.ca.gov/resources/documents/2018-base-year-emissions-inventory-report