Racing to Accelerate Electric Vehicle Adoption: Decarbonizing Transportation with Ridehailing

insight brief

January 2021

Authors

Ross McLane
Rocky Mountain Institute

EJ Klock-McCook
Rocky Mountain Institute

Shenshen Li
Rocky Mountain Institute

John Schroeder
Rocky Mountain Institute

Contributors

Alex Keros
General Motors EV/AV Program

RMI Data Science Team
Rocky Mountain Institute

Contacts

Ross McLane
rmclane@rmi.org

EJ Klock-McCook
ekmccook@rmi.org

Acknowledgments

This report was made possible with support from ClimateWorks Foundation.

HIGHLIGHTS

The race is on to deploy well over 50 million battery and plug-in hybrid electric vehicles (EVs) in the United States by 2030. This—in addition to reducing vehicle miles traveled, strategically redesigning urban areas, and improving public transit and nonmotorized transport—is necessary if we are to limit global temperature rise to 1.5°C. To achieve this scale of ambition, every opportunity for acceleration must be exploited.

Why then do we turn our attention to transportation network company (TNC) vehicles, which represent a very small portion of total miles in the United States? We believe they offer key catalytic opportunities:

- A full-time TNC driver travels approximately three times as many miles per year as the average American and therefore has a lot to gain from lower battery EV operating costs.
- Concentrated fleets of electric TNC vehicles can serve as critical anchor tenants for much-needed high-speed public charging, helping to enable broader deployment in more diverse parts of cities.
- Each vehicle serves many passengers, which, if electric, provides a valuable public education and awareness opportunity.

Rocky Mountain Institute collaborated with General Motors (GM) to better understand the challenges and opportunities of TNC electrification by evaluating a year of actual operational data—of both EVs and internal combustion engine (ICE) vehicles operating in TNC services. This helps us move past theory toward empirical conclusions and ultimately toward a clean, secure, low-carbon transportation future.

The work presented in *Racing to Accelerate Electric Vehicle Adoption: Decarbonizing Transportation with Ridehailing* is a product of RMI. Data used in the analysis was provided and approved by GM in accordance with GM privacy policies.

The Urgency of Ridehailing Electrification

The emissions from our current global transportation system pose an immense threat to our planet and human lives. Road-based transportation, overwhelmingly powered by ICE vehicles, is responsible for 6 Gt CO_2 of global emissions annually and for degrading urban air quality,[1] which contributes to 58,000 premature deaths per year in the United States alone.[2] And this problem is growing. By 2050, global demand for freight transportation is expected to triple, and demand for passenger transport is expected to double.[3]

Electrification of TNCs, such as Didi Chuxing, Lyft, Ola, and Uber, presents a unique opportunity to significantly reduce global transportation emissions. By converting conventional gasoline ridehailing vehicles to electric, we simultaneously eliminate dangerous tailpipe emissions and leverage the rapidly decarbonizing power sector to reduce overall vehicle carbon emissions. In addition to the direct benefits, paving the path for ridehailing electrification will do the same for electrification in other transportation segments. The policies and charging infrastructure needed to electrify ridehailing vehicle fleets and the broader public exposure to EVs introduced by ridehailing electrification will benefit much larger segments, such as private passenger and freight vehicles.

Ridehailing vehicles are perfect candidates for electrification because their typically high mileage makes for potentially large emissions reductions and attractive vehicle economics. Electrifying a single full-time ridehailing vehicle, which averages roughly 40,000 miles per year, can have the same emissions impact as electrifying three privately owned vehicles.[4] The same high mileages, coupled with typically lower operating costs of EVs, can generate significant cost savings over a vehicle's lifetime—something especially important for ridehailing drivers whose income is affected by their cost of operation.

Supporting the transition of TNCs from gasoline vehicles to EVs is urgent. We find that, despite rapidly reducing battery costs, ridehailing electrification is not inevitable by 2030. EVs face many barriers in ridehailing applications, aside from just high up-front prices. Relatively high charging costs created by more expensive public DC fast charging (DCFC) installations and lack of access to home charging can thwart the usually attractive economics of EVs, making them a much less appealing investment for ridehailing drivers. Even if these problems are addressed, EV cost-effectiveness is necessary but not sufficient to trigger rapid electrification.

A robust charging infrastructure network must also be established to create ridehailing driver confidence in EVs and allow EV drivers to operate as smoothly as their ICE counterparts. Delays in addressing any of these problems will not only lock in years of additional ridehailing emissions but also preclude additional reductions from other vehicle segments that could be catalyzed by ridehailing electrification. Accelerating TNC electrification is not a trivial undertaking, but it is very achievable. To make it happen, a diverse array of stakeholders, including TNCs, original equipment manufacturers (OEMs), utilities, regulators, cities, charging providers, and drivers, need to work together to overcome existing barriers and take concrete steps toward a clean mobility future.

Assessing the Hurdles to Ridehailing Electrification

Despite positive tailwinds in ridehailing electrification, the overwhelming majority of ridehailing vehicles are still powered by combustion engines. To accelerate ridehailing electrification, three major barriers must be addressed, which are common to all vehicle electrification efforts, including those of TNCs:

- **Technological Capability.** EV technology must be fully capable of replacing ICE technology for its intended application. For many applications, this means that the battery range of the EV must be sufficient to accomplish the daily mileage required of it. For ridehailing drivers, this is especially important because EVs must not only be able to accomplish the high mileages required of them but also be able to do so without the need for excessive downtime from charging, resulting in lost revenue.

- **Financial Competitiveness.** The cost of owning/leasing/renting and operating a vehicle is paramount in drivers' decisions to go electric. For electrification to accelerate, the cost of owning and operating an EV must be at least as good as, if not better than, the ICE vehicle it replaces. This is especially crucial for ridehailing drivers, whose living is directly affected by the cost of ownership of their vehicle.
- **Charging Infrastructure.** A robust network needs to be in place to instill drivers with the confidence that they can conveniently carry on their operations. Ridehailing vehicles tend to drive higher daily mileages and have disproportionately low access to home charging stations, making public charging infrastructure especially important. Insufficient infrastructure can lower ridehailing driver revenue by increasing the time it takes to find, drive to, and charge at public charging stations, therefore making charging not only inconvenient but also financially challenging. Although not sufficient on its own, a robust charging network is necessary to accelerate ridehailing electrification.

Although overcoming these barriers for electric TNCs is no small feat, it is possible. To quickly overcome them in a way that benefits broad vehicle electrification and society as a whole, TNCs, OEMs, utilities, regulators, cities, charging providers, and drivers must find common ground and ways to effectively collaborate. Technical and economic solutions can only go so far while the interests of these diverse stakeholders are not fully aligned. This report is an effort to better understand the reality of the barriers noted above and what actions each of the relevant stakeholders can take to overcome them. It is important to point out that there are several other social issues related to TNCs that are not directly affected by the choice of EV or ICE vehicle and therefore are not addressed here, such as driver earnings and urban congestion.

To understand the reality of barriers to electrification for ridehailing fleets, RMI and GM collaborated to analyze data from electric and gasoline ridehailing vehicles on GM's rental platform, Maven Gig, which operated from 2016 to 2020. Renters of Maven Gig vehicles paid a fixed weekly fee for unlimited miles, and in the case of EVs, unlimited charging at specific EVgo locations and other select locations. Drivers were required to rent for a one-week minimum, but the average rental length was approximately three months.

Maven Gig drivers were generally considered full-time ridehailing drivers because the cost structure of the rental incentivized them to offset their fixed weekly rental prices by serving as many customers as possible. Although there was a diversity of work schedules and daily mileages among drivers renting Maven Gig vehicles, the data shows that the preponderance of drivers worked full-time schedules and drove high daily mileages.

We believe that understanding and overcoming the barriers for full-time drivers is an important first step for ridehailing electrification because these drivers have greater potential benefit from the lower operating cost of EVs and greater potential emissions reductions. Furthermore, full-time TNC drivers are likely to be first movers within the TNC segment, which is itself a first mover within the broader transportation system. If the barriers to electrification cannot be overcome for full-time ridehailing service providers and drivers, electrification of similar but lower mileage vehicles segments will be an even greater challenge.

In the following sections, we assess each of the three barriers mentioned above and make recommendations for actions each stakeholder can take to accelerate TNC electrification.

Technological Capability: EVs Are Technologically Capable of Replacing ICE Vehicles in TNC Applications

For TNC electrification to accelerate, EVs must first be technologically suitable for the duty cycles of ridehailing. A suitable EV should be able to accomplish the high daily mileage of full-time ridehailing without the need for significantly more downtime (due to charging) and, consequently, longer operating hours to recoup those losses. The ability to accomplish these high mileages without excessive downtime will result in ridehailing EV drivers who are able to earn similar revenues to drivers of ICE vehicles.

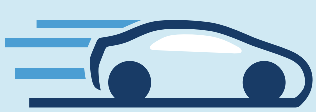
We analyzed over 6,000 Maven Gig vehicles (5,000 of which are conventional gasoline and 1,000 of which are 2017 Chevrolet Bolt EVs with an Environmental Protection Agency [EPA]-estimated 238-mile range) over the course of 2018 and 2019, mostly concentrated in Los Angeles. To compare the technical capabilities of EVs and ICE vehicles, we restricted our analysis to vehicle days that included at least four hours of driving time. Thus, we compared EVs and ICE vehicles on days that were particularly demanding for the vehicles and would therefore highlight any differences in capability. We found that on such days, EVs and gasoline vehicles drive similar daily mileages during equivalent operating times, whereas EVs exhibit only a small amount of extra downtime during operating hours compared with ICE vehicles. As time goes on and the driving range of new EV models increases (today the 2020 Bolt EV already has an EPA-estimated 259-mile range) and drivers need to charge less frequently to accomplish the same mileages, these differences in operating ability will shrink even further.

In Los Angeles, based on analysis of the empirical data, both EVs and ICE vehicles in TNC use drive for about seven hours per day. EVs drive only about nine miles (or 5.7%) less per day, a relatively insignificant difference compared with the average daily mileages of both vehicles—153 miles for EVs and 162 miles for ICE vehicles (Exhibit 1). The same EVs average only 23 minutes of additional downtime per day (6%) over ICE vehicles, which suggests that the downtime penalty EVs pay to charge in Los Angeles is relatively small compared with the typical downtime of ridehailing vehicles. The small distance and downtime penalties observed, which result in slightly lower revenues for EVs, can easily be offset by the lower operating costs of EVs when they are given access to low-cost charging.[i] Together, this data suggests that the EVs offered by Maven Gig were able to perform nearly identical tasks to ICE vehicles in Los Angeles without paying significant penalties for their dependence on battery charging.

EXHIBIT 1

Maven Gig EV and ICE Operating Statistics in Los Angeles for High-Utilization Days (greater than four hours driving time)

Total Operating Time

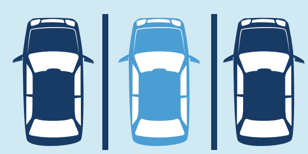


EVs: 7 hrs 14 m
ICE vehicles: 7 hrs 20 m

Average Daily Distance (miles)

EVs: 152.7
ICE vehicles: 161.9

Average Daily Downtime (excluding overnight stops)



EVs: 7 hrs 0m
ICE vehicles: 6 hrs 37 m

[i] Assuming ridehailing drivers make $11.77/hour after fees and expenses, according to a study by the Economic Policy Institute, the extra downtime of ridehailing EV drivers in Los Angeles results in $4.40 less profit per day. From estimated maintenance and repair cost savings alone—$4.30 per day using AAA estimates—these losses are almost fully recovered, not to mention the large fuel savings if drivers have access to low-cost charging.

Importantly, EV capability depends on the amount of charging infrastructure available. Although Maven Gig EVs operating in Los Angeles exhibited only 23 extra minutes of downtime over ICE vehicles, EVs in cities with less developed infrastructure like Boston and Washington, D.C., had higher downtime penalties despite driving fewer miles per day; and this is before considering extra time spent traveling to the chargers. The amount of downtime EVs experience in a city is not exactly proportional to the amount of charging infrastructure because of several complicating factors. Although this data does not prove causation, it implies the importance of robust charging infrastructure in promoting TNC electrification. We suggest more studies to better understand the effect charging infrastructure has on ridehailing vehicle operation.

In addition to the charging infrastructure, the climate of a city is also a qualifier to an EV's capability. The measured efficiency of Maven Gig EVs in Boston and Washington, D.C.—two cities with colder winters—decreased relative to Los Angeles during winter months. These variations in efficiency are an added barrier to TNC electrification in colder climates because they reduce the effective range of an EV, require increased charging times, and therefore create higher charging and opportunity costs for drivers. Anecdotal evidence supports this claim. Maven Gig drivers rented vehicles for approximately three months on average. However, in colder climates during the winter, rental periods decreased, likely due to reduced range and limited infrastructure in those areas. Note again, however, that the results here are not conclusive because the small sample size and the combination of both cold weather and less infrastructure made it difficult to separate the impacts. We recommend further study in this area.

Although colder climates will cause added challenges and require further study, we contend that the similar operating characteristics of Maven Gig EVs and ICE vehicles in Los Angeles suggest that these 238-mile range EVs, when provided a robust charging network, are capable of replacing ICE technology for full-time ridehailing. Although not all EVs have the same technological characteristics, those offered by Maven Gig demonstrate that EV technology has generally advanced to the point where it can replace ICE vehicles for ridehailing applications.

IIIIII Financial Competitiveness: Steps Need to Be Taken to Improve the Financial Competitiveness of EVs for Ridehailing

Although EVs are technologically ready for the rigors of urban ridehailing service, for electrification to accelerate, they must also command a cost advantage over ICE vehicles. To assess the cost-competitiveness of full-time ridehailing EVs compared to ICE vehicles, we analyzed the total cost of ownership (TCO) between representative vehicles in 15 major metropolitan areas. We find that driver-owned (as opposed to rented or leased) full-time ridehailing vehicles that rely exclusively on public DCFC do not currently have a TCO advantage in any of these metropolitan areas given current policies, incentives, available infrastructure, and electricity rate structures.

It is important to note that this conclusion is based on the assumptions that ridehailing vehicles (1) operate on a full-time schedule and drive relatively high daily mileages, (2) are driver-owned, and (3) charge exclusively with public DCFC at standard charging rates (those offered to the public with no special discounts). A comprehensive list of the assumptions of the TCO model are listed in Exhibit 2. We choose these assumptions because we believe that they are reasonable and useful for the study of ridehailing EVs for the following reasons:

1. Full-time ridehailing vehicles are high-mileage vehicles that can benefit from the typically lower operating cost of EVs and are therefore likely to be first movers within the ridehailing vehicle segment.
2. The majority of vehicles in current ridehailing applications are driver-owned.
3. Ridehailing drivers have disproportionately low access to home charging installations, making them rely much more heavily on public DCFC. We therefore assume in our baseline TCO model that ridehailing drivers exclusively rely on public DCFC. This is much different than private EVs, which get 80% of their energy from home charging.[5]

EXHIBIT 2

Base Case TCO Modeling Assumptions

Metropolitan Areas	We analyze 15 metropolitan areas, which represent some of the most populous urban areas in the United States. Among them are New York City, Los Angeles, Atlanta, Miami, and Chicago.
Driver Type	We analyze full-time ridehailing drivers because these drivers have the largest potential savings due to their high mileages. Based on average daily mileages from Maven Gig fleet data and a 246-day working year, full-time EVs operate 38,000 miles per year and full-time ICE vehicles operate 40,000 miles per year.
Vehicle Models	We consider an EV with the average characteristics of a Chevrolet Bolt EV 2020 and a Nissan LEAF S Plus 2020. We choose models with roughly 250-mile quoted ranges because we assume these are the most desirable vehicles for ridehailing due to their cost-effectiveness in terms of charging and opportunity costs. The actual efficiency of EVs in our analysis is based on combined miles per gallon equivalent (MPGe), which gives an average 220-mile range. We consider a gasoline model with the characteristics of the Chevrolet Malibu 2020, Chevrolet Equinox 2020, and Chevrolet Trax 2020, with a city/highway average of 28 MPG, based on the observed average speed of 22 mph.
Up-front Purchase Price	Up-front purchase prices are based on Kelley Blue Book Fair Purchase Prices, which represent up-to-date averages of real purchase prices from across the United States. We subtract any applicable local or state incentives but exclude the federal tax credit, as the tax credit has already been phased out for the EVs from several manufacturers.
Charging	Because Maven Gig customer data indicates that most drivers did not have access to home charging, we assume no access to home level 2 (L2) charging in the base case. More generally, there is little data on ridehailing drivers' current access to home charging; however, drivers are believed to have disproportionately low access to L2.[6] We therefore assume a conservative lower bound that no ridehailing drivers currently have home charging, instead relying exclusively on public DCFC.
Refueling Prices	Public DCFC prices are derived from EVgo membership charging rates, priced in dollars/minute. Based on the observed charging sessions of the EVs included in the data set, the average power is 45kW. From this, we calculate the average charging price of EVgo DCFC across all studied metropolitan areas to be $0.36/kWh. We do not include any business-to-business charging price discounts or similar incentives in this price. For gasoline prices, we take the 10-year average from 2010 to 2020.[7]
Opportunity Cost	We take a unique approach to estimating the opportunity cost of charging for ridehailing vehicles. Rather than assume all public charging incurs opportunity cost, we estimate opportunity cost by using the difference in downtime between a Maven Gig EV and a Maven Gig ICE vehicle to estimate the amount of operating time an EV driver misses out on.
Maintenance, Repair, and Insurance	Maintenance and repair costs are estimated by AAA to be $0.089/mile for gasoline vehicles and $0.066/mile for EVs.[8] Insurance costs are based on Kelley Blue Book estimates.[ii]

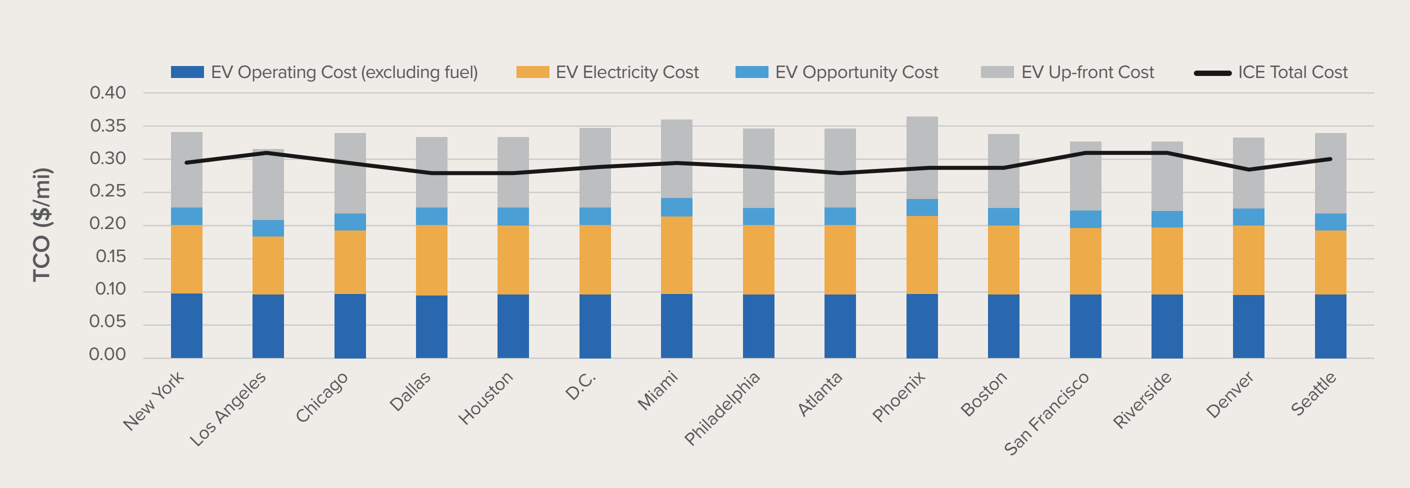
[ii] In September 2020, Consumer Reports published lifetime maintenance costs for gasoline, hybrid, and electric vehicles. This data is lower than those used in this report and would decrease the relative cost of EVs by approximately 2%.

Recent innovations promise to make ridehailing EVs more financially competitive with ICE vehicles. Leasing and rental models, such as Lyft's Express Drive and Uber's partnership with Avis, have the potential to both reduce the barriers of the up-front price for EVs in ridehailing and make the technology easier to try without long-term commitment. Additionally, Uber and EVgo recently announced a partnership by which Uber drivers will receive up to 25% off standard EVgo DCFC rates, making DCFC less expensive for a segment that heavily relies on it. Because these innovations are nascent and not yet universal in the TNC market, we use the assumptions listed in Exhibit 2 as the basis for TCO comparison; however, we discuss these innovations and their potential positive impact in greater detail in the following sections.

Based on the assumptions in Exhibit 2, no EV in any studied metropolitan area breaks even on a TCO basis with its gasoline counterpart, as shown in Exhibit 3. The minimum difference in TCO across these areas is $0.01 per mile (3% higher than ICE vehicles) in Los Angeles, where low charging costs, higher-than-average gasoline costs, and generous EV incentives create a hospitable environment for EVs. On the other end of the spectrum, Phoenix's high charging costs, lower-than-average gasoline costs, and lack of local incentives increase the cost gap to $0.08 per mile (27% higher than ICE vehicles).

EXHIBIT 3

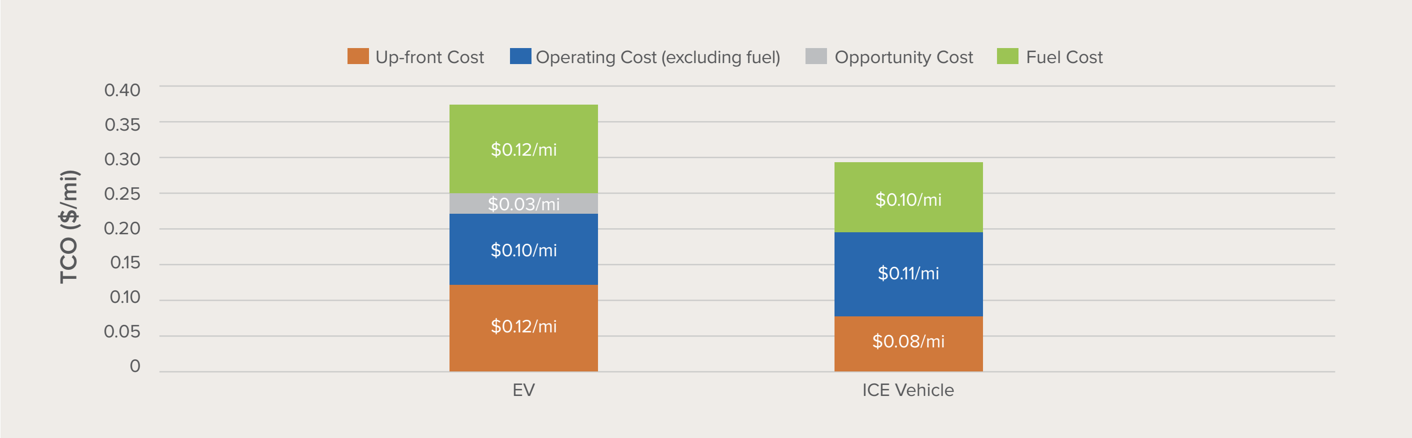
TCO Comparison across 15 Major US Metropolitan Areas



The retail price of DCFC charging is an important factor contributing to EVs' financial challenges in these regions. A high-mileage EV with access to low-cost home charging would typically generate significant operational savings, easily offsetting its higher up-front cost over the course of a 10-year lifetime. However, for these full-time vehicles relying on public DCFC, the cost of charging at $0.09–$0.11/mile is similar to gasoline at $0.09/mile. This, combined with the small but important charging opportunity cost, eliminates the operating cost advantage in all of the 15 metropolitan areas. Without an operating cost advantage, the TCO gap of ridehailing EVs increases, rather than shrinks, over the vehicle's lifetime. This can be seen clearly in a side-by-side comparison of the TCO components of EVs and ICE vehicles in Phoenix in Exhibit 4.

EXHIBIT 4

TCO Component Breakdown in Phoenix



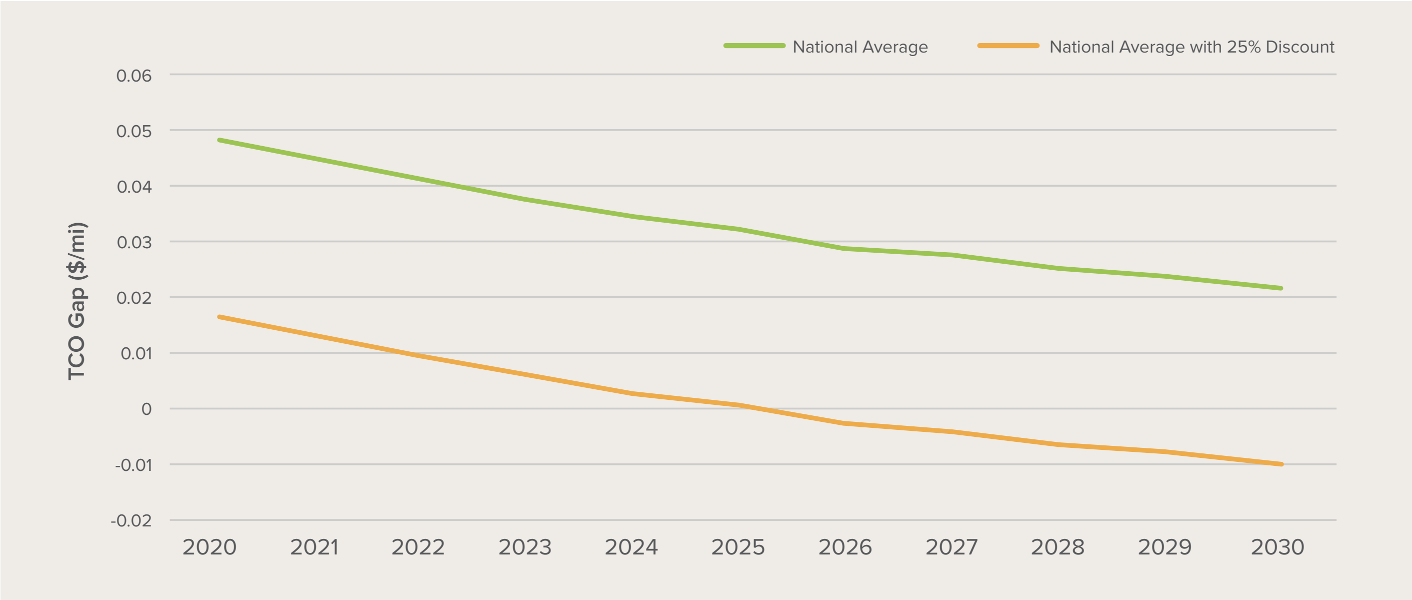
We find that for these ridehailing EVs, the projected declines in purchase price, due mostly to decreasing battery prices, will not be sufficient to bring EVs to TCO parity with ICE vehicles in a reasonable time frame. The extent to which declining battery prices translate into lower EV prices in the medium term is inhibited by the fact that (1) most EVs currently are not profitable for manufacturers, meaning that at least some of the battery savings will not be passed on to consumers, and (2) as consumers demand ever more capable EVs, battery savings may be offset by larger, higher-performance batteries. If the up-front price of EVs does decline, as many expect, we find that only three metropolitan areas will reach TCO parity in ridehailing by 2030 due to these reductions alone, given the assumptions noted above.

Exhibit 5 shows the effect of falling EV purchase prices on the national average TCO gap between ridehailing EVs and ICE vehicles. Based on Bloomberg New Energy Finance projections of component prices for medium EVs (those with 250-mile ranges in EPA test cycles), we assume that the price of an EV drops 10.2% per year, where 8.8% of that decline is due to decreasing battery costs, 1.2% is due to decreasing powertrain costs, and 0.2% is due to the decreasing cost of all other vehicle components.[9] Although ICE vehicle prices are expected to increase over time due to added technology to meet emissions requirements, reducing the time to TCO break-even, we take a conservative estimate and ignore those increases for our purposes.

Although today's retail DCFC prices imply that ridehailing EVs will not break even by the end of the decade, the impact of fleet discounted prices, such as those offered by EVgo to Uber drivers, pushes forward the break-even point closer to mid-decade and demonstrates the importance of such an approach (Exhibit 5). Policy measures are needed to pull this forward even further until technology improvements and scale can sufficiently reduce the cost of DCFC, thus accelerating electrification consistent with what is required to limit global warming to 1.5°C.

EXHIBIT 5

Average TCO Gap between Ridehailing EVs and ICE Vehicles under Different Charging Price Scenarios (2020–2030)



Waiting for TCO to break even for electric full-time ridehailing vehicles under their natural economic progression could be detrimental. Full-time drivers stand to benefit the most within the ridehailing segment, and the ridehailing segment itself is likely an early mover in the transportation system as a whole, helping electrification push past the wealthy or environmentally conscious early adopters to the early majority. Additionally, break-even is only the first step—for adoption to truly accelerate and overcome behavioral barriers, EVs need to command a significant cost advantage over ICE vehicles, something that has a very uncertain timeline without concerted policy efforts.

Finally, even with a cost advantage, the turnover rate for American vehicles is slow (at its current rate, it takes about 15 years to turn over the entire light-duty vehicle fleet),[10] meaning that even very cost-competitive EVs will take years to propagate through the entire passenger vehicle fleet—time we do not have. We must act now to employ bold policies that reduce costs and promote EV adoption in ridehailing if we are to stay on a timeline that is consistent with achieving key interim climate goals by 2030.

In service of this target, we recommend four major levers to close the cost gap between EVs and ICE vehicles: (1) increasing access to L2 charging; (2) reducing DCFC charging prices; (3) reducing initial barriers to vehicle ownership, leasing, rental, and usage; and (4) reducing the opportunity cost of EV charging. These levers are not meant to be an exhaustive list of strategies to accelerate EV adoption but instead a set of tools to bring EVs to TCO parity with ICE vehicles and spark large-scale TNC electrification. For maximum impact, a diverse set of stakeholders, including policymakers, utilities, regulators, charging providers, TNCs, and OEMs, need to work together, each doing their part to influence these levers.

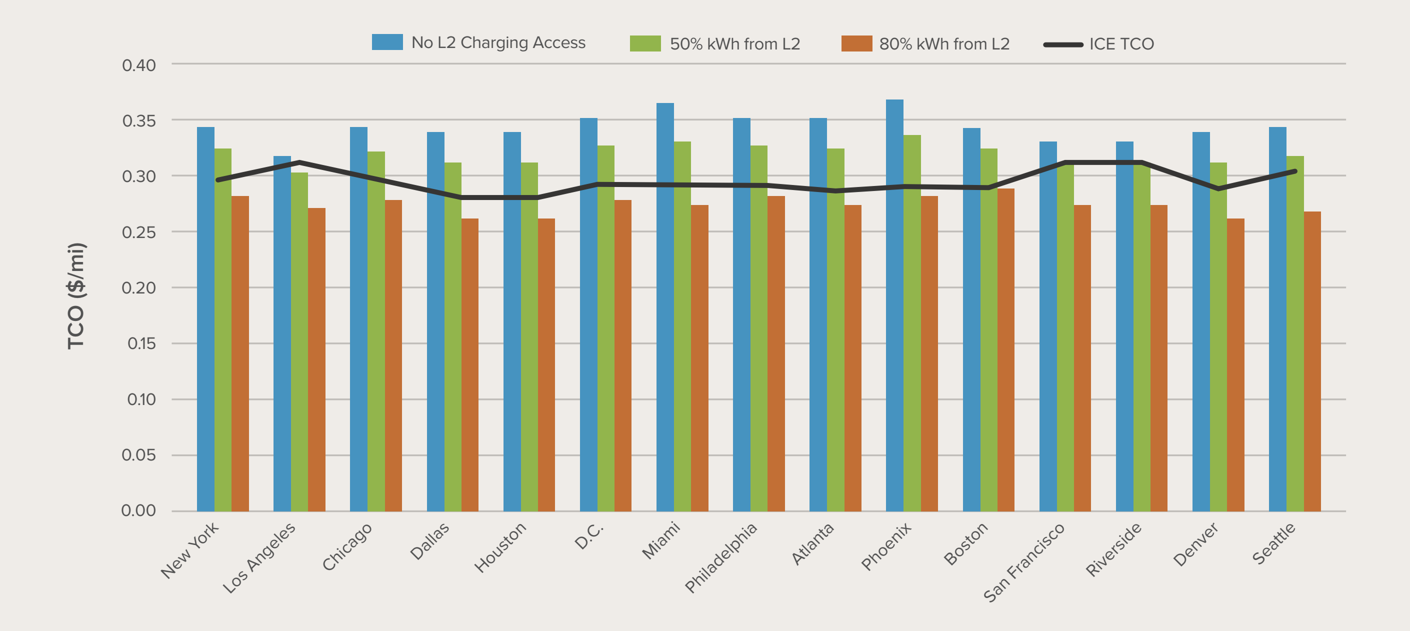
Increase Access to L2 Charging

An effective way to lower the TCO of ridehailing vehicles is by increasing driver access to lower-cost charging, such as L2 home charging. L2 charging only requires a 240-volt circuit, a relatively inexpensive charger, and the labor of an electrician to install it, usually amounting to roughly $1,400 for residential applications.[11] It then provides charging at residential electricity rates, which average $0.13 per kWh in the United States compared with $0.35 per kWh average for retail DCFC, creating the opportunity for significant operational cost savings.[12]

In Exhibit 6, we investigate the effect of increased access to L2 charging on a full-time ridehailing EV's TCO. We model three scenarios: 0%, 50%, and 80% of a driver's charging coming from an L2 residential charger. We find that when EV drivers are able to use L2 charging for 80% or more of their charging, they have a cost advantage over ICE vehicles in all major metropolitan areas studied.

EXHIBIT 6

Effect of Increased L2 Usage on EV TCO



According to our analysis of Maven Gig vehicle data, ridehailing drivers with reliable access to an L2 charger at or near their home are able to derive the majority of their energy from that charger. We determined this by evaluating how frequently the vehicle's overnight stop is sufficiently long enough to fully recharge. With this and the average miles traveled per day, we estimate that full-time ridehailing drivers with reliable access to an L2 charger can accomplish approximately 90% of their total driving miles with L2 charging in the summer months and 80% in winter months, with the rest needing to come from public charging DCFC (the seasonal difference is because EV efficiency is lower in colder months).[iii] This implies that, even in cold climates, EVs with reliable access to L2 charging are a better investment than ICE vehicles.

The number of full-time ridehailing drivers with access to L2 chargers is the problem. The International Council on Clean Transportation estimates that, for a variety of reasons, only 44% of ridehailing drivers have the ability to install L2 charging at their residences (2020).[iv] Full-time drivers, who tend to have lower incomes, have even less ability to install L2 home chargers. In addition, an emerging rental model for ridehailing EVs, which allows drivers to obtain the EV without paying the high up-front price, disincentivizes charger installation because it will be a sunk cost if they choose to stop renting.

Exhibit 7 outlines some important ways to increase access to L2 charging for ridehailing drivers.

EXHIBIT 7

Recommendations for Improving Access to L2 Charging

Recommendation	Stakeholders	Description
Incentives for L2 installation at single-family homes	States, municipalities, utilities	Financial incentives offered by municipalities and public utilities for home charging installation can be effective in overcoming the cost barrier to L2 charging. These incentives often come in the form of either rebates or tax credits and are based on the cost of charging installation. The Los Angeles Department of Water & Power, a California utility, for instance, offers **a $500 rebate for home EV charging installation for its residential customers**.
Incentives for L2 installation at MUDs	States, municipalities, utilities	Because many ridehailing drivers do not live in single-family homes with private parking, prioritizing L2 charging access in multi-unit developments (MUDs), such as apartment buildings, is crucial. **The Smart Columbus Electrification Program** is one example of a municipal program that improves MUD access to L2 charging by providing rebates to property owners for installing charging stations for their tenants.
EV-ready building ordinances	States, municipalities	States and municipalities can pass building codes that require a certain percentage of parking spaces in public or private buildings be made ready for eventual charger installation. Boulder County, Colorado, for example, **requires new construction to have the necessary conduit and pre-wiring for EV chargers**.
MUD tenant charging installation mandates	States, municipalities	California, Colorado, and other states require landlords to approve tenants' requests to install EV charging at the tenants' expense, with certain limitations. Mandates such as these may be powerful motivators for a ridehailing driver's to adopt an EV.
L2 charging packages	OEMs, TNCs, charging providers	OEMs and TNCs can work with L2 charging providers to offer built-in or discounted L2 charging for drivers who purchase a vehicle or use it on their platform and whose home can accommodate it. **Uber, for instance, is partnering with charging provider Enel X** to offer discounts of up to $125 off charging packages for Uber drivers.

[iii] Estimates assume that a driver will demand public fast charging when their vehicle has 50 or fewer miles of range left on any given day.

[iv] This is based on the assumption that 17% of all apartments, 49% of all attached multi-unit houses, and 68% of all detached houses (also known as single-unit dwellings) could reasonably install L2 charging and that ridehailing drivers are more likely to live in apartments and multi-unit houses (*Observed Charging Rates in California*, UC Davis Plug-In Hybrid & Electric Vehicle Research Center).

An added benefit of increasing L2 charging access is that, for most ridehailing drivers, charging at home while not driving reduces the opportunity cost incurred by forgoing paid rides to use public DCFCs during their shift. Through analysis of Maven Gig vehicle data, we find that 86% of vehicle days across all 6,000 vehicles have continuous stops longer than six hours, roughly the amount of time needed to fully charge at an L2 charger. This suggests that most full-time drivers have enough downtime at their residences to benefit from L2 charging and its lower associated opportunity cost.

In addition, L2 charging is easier to manage for grid benefits, matching supply and demand of electricity. In the future, as both EVs and variable-output renewables continue to expand, managed L2 charging can provide critical support to balance the electricity grid—whether solar generation during the day or wind generation at night. Although this is more challenging for DCFC, unlike the general public, TNC drivers may be more price sensitive and flexible around when they use DCFC and could be incentivized to charge at times that benefit the grid given the proper price signals.

Although increased L2 charging lowers costs to the driver, it is not the one-stop solution for all drivers. Those without access to charging at home could use public L2 stations, but they must be located in close proximity to residences because of the long charge times. As a consequence, public L2 charging must be much more ubiquitous than DCFC to be effective. A complete charging ecosystem for ridehailing vehicles must include a mix of L2 charging and cost-effective public DCFC.

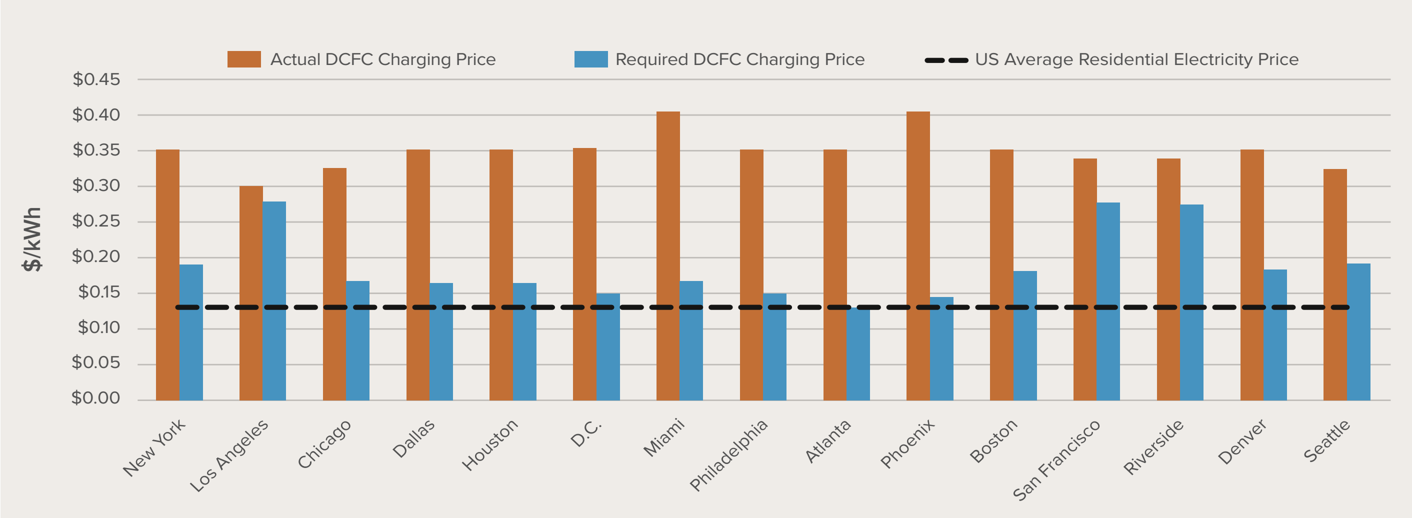
Reduce DCFC Charging Prices

Relying fully on public DCFC given current retail prices, rather than using it for higher-value top-ups during a shift, means that the operational costs savings of an EV are eliminated. But, for ridehailing drivers with no possible access to L2 charging, public DCFC is a necessity. Even for drivers with access to L2 charging, DCFC networks are a critical safety net for very high mileage days. As charging power increases over time, the EV charging experience with DCFC will become even more similar to refueling an ICE vehicle, and more drivers will likely be willing to rely more heavily on DCFC infrastructure. Therefore, it is critical to reduce DCFC prices and the underlying costs of hardware, siting, and electricity.

To understand the magnitude of DCFC price reduction necessary, we have calculated the amount charging prices would have to decrease for ridehailing EVs, fully dependent on DCFC, to reach TCO parity with ICE vehicles in their respective cities, assuming no other policy support. In Exhibit 8, we show both the current EVgo DCFC charging price in each metropolitan area and the price needed for TCO parity. In general, the current DCFC prices of $0.30–$0.40 per kWh would need to drop to $0.12–$0.27 per kWh for EVs to break even on a TCO basis; however, price differentials vary widely depending on regional gasoline and electricity prices and local incentives. Whereas some metro areas need little or no price reduction, others require upward of 60% reduction to achieve TCO parity. (Assumptions are detailed in Exhibit 2.) This degree of price reduction is simply not feasible because of the factors laid out below. Therefore, reduction in DCFC prices can only be part of the solution.

EXHIBIT 8

Actual DCFC Charging Price vs. DCFC Electricity Price Needed for TCO Break-Even



The price consumers pay for DCFC charging is a result of a couple of factors. First, installing and operating the necessary hardware to deliver the high-powered electricity needed for fast EV charging is expensive. The costs of hardware, construction, permitting, siting, and land for these installations are naturally built into the price that consumers pay for DCFC.[v] In addition to these costs, DCFC charging providers must pay for electricity from the grid, typically on a commercial or industrial electricity tariff. These tariffs penalize sporadic, high-powered demand, which is currently typical of many DCFC stations. As a result, the rates for this type of charging nationwide are expensive compared with home charging and are equivalent to gasoline prices.

However, those high prices are based in part on the low utilization of most public stations. This dynamic creates a different version of the familiar chicken-and-egg problem: high charging costs from low utilization prevent faster EV adoption, which in turn perpetuates the low utilization and high charging costs.

The opportunity presented by meaningfully large fleets of EVs in TNC use is that they increase charger utilization to the point where the underlying cost of electricity becomes much less expensive. This was directly observed in Los Angeles, where the volume of demand generated by the Maven Gig EVs offered utilization benefits and created downward pressure on electricity costs. The question then becomes how to leverage the utilization that a fleet of this size brings to lower charging costs for TNC drivers and for the public in general. This is a chance to flip the chicken-and-egg problem on its head and turn it into a virtuous cycle, where more EVs lead to lower-cost charging, which leads to more EVs, and so on. In November 2020, EVgo and Uber announced a discount program that will provide up to a 25% discount on retail charging prices.[13] This type of preferred fleet pricing will improve driver economics, especially in places with relatively robust infrastructure in place.

[v] A more detailed breakdown of cost components for EVgo DCFC can be found at https://www.evgo.com/wp-content/uploads/2020/05/2020.05.18_EVgo-Whitepaper_DCFC-cost-and-policy.pdf.

To kick off this cycle in locations that do not already have a robust charger network, tariffs can be redesigned to recover costs in ways that do not penalize low load factors (i.e., low charger utilization). RMI's *EVgo Fleet and Tariff Analysis* explores in detail the types of tariff reforms necessary to create a conducive business environment for public DCFC and decreased charging prices. Currently, utilities such as Pacific Gas & Electric (PG&E), Southern California Edison, and Xcel Energy have implemented tariffs specifically designed to reduce demand charges, which will help establish the EV market while use is low. As the market matures and utilization improves, these measures may no longer be necessary—a similar philosophy to vehicle rebates or tax credits.

In addition to utility tariff reform, Exhibit 9 outlines other recommendations we believe can assist in the reduction of DCFC charging prices for ridehailing fleets.

EXHIBIT 9

Recommendations to Reduce Public DCFC Prices

Recommendations	Stakeholders	Description
Utility tariff reform	Utilities, regulators	Reform electricity tariffs to recover costs without penalizing low-utilization DCFC stations. Modified demand and energy charges or time-of-use rates that incentivize charging at times that benefit the grid are possible examples. This can kick off a virtuous cycle where lower electricity costs lead to more EVs on the road, which in turn brings more utilization to charging stations, further reducing electricity costs. Examples of utilities with these tariffs include **PG&E, Southern California Edison,** and **Xcel Energy**.
B2B discounts for TNC fleets	TNCs, OEMs, charging providers	There are mutual benefits for ridehailing EV fleets and charging providers. Charging providers can benefit from higher utilization resulting from large ridehailing fleets, while ridehailing fleets benefit from access to public DCFC networks. As a result of this mutual benefit, charging price discounts can be given to ridehailing fleets, which provide cost-effective charging to drivers, while still providing sufficient profit margins for charging providers. This was observed in Los Angeles, where the volume of demand generated by the Maven Gig EVs offered utilization benefits and placed downward pressure on costs. Similarly, Uber has announced that its drivers can obtain up to **25% off standard EVgo rates**.
Promote high utilization, dedicated ridehailing stations	TNCs, OEMs, charging providers	Building high-utilization, dedicated public stations for ridehailing fleets is another way to combat high DCFC charging prices. Dedicated fast-charging stations for ridehailing fleets guarantee both ridehailing access and increased station utilization, therefore lowering costs to the charging provider and giving them more room to lower charging prices for the drivers. In 2018, **Maven Gig and EVgo partnered to build such dedicated stations in Los Angeles**. An added benefit is that the site agreements and electrical upgrades can then be leveraged to provide additional public charging ports.
Charging price subsidies	States, municipalities, utilities	Charging prices can be reduced through direct subsidies on the per-kWh price that consumers pay. The advantage of discounting electricity for public DCFC is that it directly supports electric miles and disproportionately benefits those who do not have private parking or the means to install a charger of their own.
Low-carbon fuel standard (LCFS)	States, federal government	An LCFS, as implemented in California, collects money from those who produce fossil fuels and, among many other things, provides credits for installed public DCFC chargers. This in turn can lower the price paid to use the DCFC chargers.

Reduce Initial Barriers to Vehicle Ownership and Usage

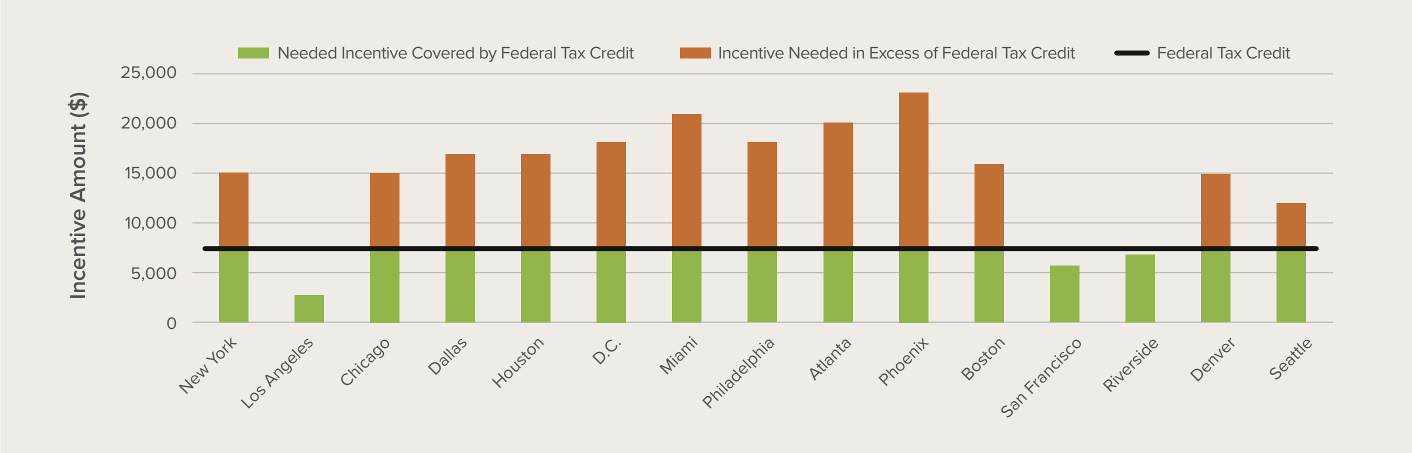
In addition to reducing charging prices, policies that lower the initial price barrier of EVs are also an effective way to both reduce EV TCO and make EV purchases viable for drivers who would not otherwise be able to afford one. The EVs analyzed in this study were priced roughly $10,000 above comparable gasoline vehicles, making them unattainable for many consumers. Although this price will decline over time (with the caveats discussed above), under current conditions this decline will not reduce ridehailing EV TCO quickly enough to reach cost parity in a time frame that is consistent with 2030 climate targets.

Some of the most common policies to reduce the initial price barrier of EVs are rebates and tax credits used by states, municipalities, and, notably, the federal government. The federal EV tax credit provides up to a $7,500 tax credit for an EV purchase but phases out after an automaker reaches 200,000 plug-in EVs sold. Currently, GM and Tesla are the only two automakers to have reached the threshold; thus, those who buy EVs from these companies no longer qualify for this federal tax credit. In addition to the federal tax credit, 12 states also currently offer EV rebates or tax credits. A select few local communities and utilities offer up-front EV purchase incentives as well, though it is more common for utilities to offer other forms of financial incentives, such as rebates on home charging or reduced electricity prices for EV owners based on time of use.

Up-front purchase incentives are most effective if used in conjunction with the levers discussed above, which are intended to ensure operational cost savings. We calculate that, for full-time ridehailing vehicles dependent exclusively on current retail DCFC charging prices, the rebates needed for TCO parity, assuming no other policy support, would be unworkably high (Exhibit 10). This suggests that up-front purchase incentives are best used on ridehailing EVs as part of a larger suite of supportive policies for ridehailing electrification.

EXHIBIT 10

EV Incentive Needed for TCO Parity with No Other Policy Support



An up-front purchase incentive designed to maximize benefit for ridehailing drivers would come in the form of a rebate and take into consideration full-time drivers' typically lower income. Although estimates of driver pay vary widely, it is safe to say that ridehailing drivers tend to fall into low- or middle-income brackets.[v] As a result, the efficacy of EV tax credits is limited by an

[v] The Economic Policy Institute estimates that Uber drivers' W-2 equivalent wages were roughly at the 10th percentile of all wage and salary workers' wages in 2018.

applicant's tax liability, so tax credits are not the most effective way to reduce the up-front cost. Instead, we recommend an up-front purchase rebate, which allows drivers to claim the full amount of the incentive at the point of sale regardless of tax liability.

Another important way to reduce the up-front price barrier to EV adoption is short-term rentals. Rental platforms like Lyft's Express Drive and a partnership between Uber and Avis can bypass the high purchase prices of EVs altogether and introduce drivers to EV technology without long-term commitments. This can make EVs accessible to drivers who otherwise would not be willing or able to purchase an EV outright.

EV rental platforms have a couple of other unique benefits. First, they transfer risk of vehicle failure and technology obsolescence from the driver to the renting entity. For instance, if a vehicle has severe or unexpected maintenance problems, a large company is much better able to spread that cost across all of its assets. Second, rental companies have more buying power and access to different economics than individuals. Didi Chuxing, for instance, partners with car manufacturers and leasing companies to procure ridehailing vehicles at bulk or wholesale prices.[14] These lower wholesale vehicle costs result in rental platforms being able to reduce vehicle prices in ways that would be impossible for individuals.

In addition to up-front purchase incentives and rental EV platforms, Exhibit 11 presents a few other ways for stakeholders to tackle the initial purchase barrier of EVs to stimulate ridehailing electrification.

EXHIBIT 11

Reduce Barrier to Entry for EVs

Recommendation	Stakeholders	Description
Up-front purchase rebate	**States, municipalities**	Rebates that are tied to an applicant's income level and are applicable to new, used, and leased EVs can reduce EV up-front purchase prices, especially for ridehailing drivers. **Oregon's Clean Vehicle Rebate Program** is a good example, offering a "Charge Ahead" rebate program that provides rebates for used and leased vehicles as well as increases in amounts for lower income applicants.
Promotion of used EVs	**States, municipalities, TNCs, OEMs**	Currently, EVs depreciate faster than gasoline vehicles. As a result, the price of used or off-lease EVs is much closer to that of equivalent gasoline vehicles. According to the Kelley Blue Book, a 2017 Chevrolet Bolt EV with 30,000 miles on it is roughly $17,000, less than half its original price, while an equivalent Chevrolet Equinox is $16,000. Because of these attractive economics, promoting the used EV market can be an immediate way to overcome the high-price premiums that EVs currently command. Promotion of the used EV market can come in the form of rebates applicable to used vehicles or programs to reduce real or perceived risk associated with used batteries.
Scrap-and-replace incentives	**States, municipalities**	Incentives that require the trade-in of an old, inefficient, gas-powered vehicle in exchange for a rebate on an EV. This has the added benefit of increasing vehicle turnover as well as reducing the up-front cost of EVs.
Rental EV platforms	**TNCs, OEMs**	Rental EV platforms can reduce the initial purchase barrier for EVs while introducing EV technology without long-term commitment. Rental EVs transfer risk of vehicle failure and obsolescence to the renting entity and can benefit from wholesale prices available to the renting entity. See GM's Maven Gig, Lyft's Express Drive, and Uber's partnership with Avis for examples.

Reduce the Opportunity Cost of EV Charging

The final lever we recommend to improve the economics of ridehailing EVs is to reduce the effect of EV opportunity costs associated with charging. Opportunity costs are incurred by the extra time it takes to charge at public fast chargers compared with gas stations, which takes time away from servicing ridehailing customers. A poorly planned, undersized charging network compounds these opportunity costs by requiring route diversions and queuing for public charging. This can not only affect ridehailing drivers' bottom lines but also can be inconvenient and deter drivers from even choosing an EV in the first place.

As demonstrated by the fleet data in Los Angeles, robust charging infrastructure can reduce the costs created by queuing at overused chargers, reduce route diversions needed to find a charger, and allow drivers to align their charging times with preexisting downtimes, such as lunch or bathroom breaks. Recommendations to support charging infrastructure build-out are outlined further in the next section on charging infrastructure. In addition, Exhibit 12 outlines other levers that can reduce the impact of charging opportunity costs.

EXHIBIT 12

Recommendations to Reduce Opportunity Cost

Recommendation	Stakeholders	Description
High-occupancy vehicle (HOV) lane access/ airport pickup priority	States, municipalities	Granting EVs preferential access to HOV lanes and airport pickup lines can reduce the amount of downtime ridehailing vehicles waste in traffic and queuing to pick up airport customers. Those reductions in downtime can cancel out the increased downtime EVs require over ICE vehicles to charge their batteries.
Charging infrastructure build-out	States, municipalities, charging providers, TNCs, OEMs, utilities	Intelligently designed, ubiquitous charging infrastructure can serve to reduce EV downtimes by shortening queues for chargers; limiting route diversions to find chargers; and aligning charging with preexisting downtimes, like lunch times or bathroom breaks. Recommendations for the build-out of a robust charging network are detailed in the following section.
EV revenue compensation	TNCs	To compensate for the lost revenues attributable to EV charging times, TNCs can offer preferential rates for EV drivers. Uber, for instance, has announced that EV drivers can make $1 extra on every trip up to $4,000 per year, and they can receive an extra 50 cents per trip from riders who choose to use the **Uber Green** option.

Charging Infrastructure: Sufficient Infrastructure Is as Essential as Low-Cost Operation

Insufficient public charging infrastructure and its drag on ridehailing electrification will not improve "naturally" over time. Instead, charging infrastructure is caught in what is often called the chicken-and-egg problem: charging providers need high enough utilization from EVs to earn returns on their investments, but that requires high penetration of EVs on the road, something that is dependent on sufficient public charging infrastructure.

Several things can and are being done to break out of this cycle, namely policies to reduce the costs to charging providers and make installations a more attractive investment (see Exhibit 13). The Utah Department of Environmental Quality, for instance, offers a grant of up to 50% of the purchase and installation cost of a preapproved electric vehicle supply equipment (EVSE) project (including L2 and DCFC EVSE). Despite these efforts, sufficient infrastructure to support ridehailing is still a barrier. In 2017, Uber ran a six-month EV pilot in London, which concluded with drivers reporting insufficient public infrastructure to support their daily routines. Although infrastructure in the United States has been improving in recent years, many US ridehailing pilots have had to be restricted to the relatively few cities with enough infrastructure to support them.

EXHIBIT 13

Recommendations to Accelerate Charging Infrastructure Deployment

Recommendation	Stakeholders	Explanation
Charger construction incentives	States, municipalities	Providing incentives for charging station construction can unlock more private investment by reducing the high up-front capital cost of construction and therefore reducing the payback period of investment. See the **Utah Department of Environmental Quality's grant for workplace EVSE** as an example.
Utility rate-basing of make-ready charging infrastructure	Utilities, regulators	Utility companies can incorporate the cost of electrical infrastructure needed for charging station installations (make-ready) into the general customer electricity rate structure (rate base). Doing so shares the cost and risk with the operator and leverages the utility's capital, which likely has a longer investment horizon than the private market. See, for example, the **San Diego Gas and Electric EV Charging Infrastructure Program**, which designs and builds make-ready infrastructure for medium- and heavy-duty fleets in California.
Streamline site development and other "soft costs"	States, municipalities	Barriers to widespread charging are not strictly financial. The difficult processes of arranging land leases, permits, grid connections, and code compliance all cost time and therefore money to the charging provider, slowing construction and reducing the number of viable sites. The situation is made worse by the fact that these procedures vary from locality to locality. Simplifying and standardizing these processes can yield a large return on a small investment. See RMI's ***Reducing EV Charging Infrastructure Costs*** for more detail.
Building at scale	Charging providers	Building larger fast-charging station sites increases asset utilization, smooths the peak power—which generates the demand charges that are a large proportion of the final electricity bill—and spreads fixed costs over more chargers, resulting in a more profitable proposition for charging providers. **This approach is used in China**, where there are explicit government incentives to build charging stations at scale.
Analytically informed network design	States, municipalities, charging providers	Analyzing vehicle travel patterns to inform charger location can better ensure that charging infrastructure is used where it is built. RMI is developing a package of tools in an effort to predict the charging demands of electric ridehailing fleets based on observed travel patterns and site charging stations to maximize utilization. Future work will outline these efforts.

The need for robust public charging networks to support both ridehailing and other vehicle electrification is urgent. Even if EVs are both technologically capable for their intended application and financially competitive with ICE vehicles, an insufficient charging network can completely stymie forward momentum in electrification. Bold policies need to be put in place now to ensure sufficient charging infrastructure.

Conclusion

Ridehailing electrification has an important role to play in the decarbonization of the larger transportation system. Converting a ridehailing vehicle from a conventional gasoline engine to an electric motor eliminates toxic tailpipe pollutants, has the potential to reduce the same amount of CO_2 as electrifying three passenger vehicles, and can catalyze electrification in other vehicle segments.

Though EVs are technologically ready for the rigors of urban ridehailing, in most major US metro areas studied, they are not yet financially competitive with ICE vehicles. We estimate the average TCO of full-time ridehailing EVs fully dependent on public DCFC will not reach parity with ICE vehicles in the next decade without intervention. Waiting this long to start transitioning to a cleaner mobility system would lock in years of transportation emissions and throw us off the trajectory needed to limit global temperature rise to 1.5°C by 2030. But we have the power to dramatically push this timeline forward by reducing the costs of EVs and instilling confidence in ridehailing drivers with targeted interventions.

To achieve climate commitments, a wide array of stakeholders, including TNCs, OEMs, utilities, regulators, cities, charging providers, and drivers, must align on the goal of ridehailing electrification and the actions and collaboration needed to get there. Our recommendations for these stakeholders fall into four broad categories: (1) increasing access to L2 charging; (2) lowering the cost of DCFC charging; (3) lowering the initial barrier to EV ownership, leasing, rental, and usage; and (4) reducing the opportunity cost of charging for ridehailing drivers.

Each stakeholder has a unique perspective and ability to influence these levers. Utilities, for instance, can change the way electricity is priced for DCFC; states and municipalities can lower purchasing barriers and introduce policies that the private sector cannot; and private sector entities, like TNCs, OEMs, and charging providers, can capitalize on their mutual benefits to lower costs for ridehailing drivers and encourage them to electrify. When each recommendation we make composes part of a larger suite of actions, the burden for each individual lever is reduced. We recommend relevant stakeholders that are interested in promoting the electrification of ridehailing vehicles analyze how each of these measures can be best employed in their own regions.

Although EV financial competitiveness and technological capability are necessary for EV adoption to accelerate, they are not sufficient in themselves. A robust charging network is also a precondition for ridehailing EV adoption—without it, drivers will not have the confidence to adopt EVs. A robust charging network is not naturally occurring or inevitable. Low station utilizations remain a challenge for charging providers, while charging stations themselves are necessary to improve EV adoption and station utilization.

However, introducing critical policies to change this feedback loop can turn the vicious cycle into a virtuous one. Lower electricity costs for charging providers can lower charging prices for consumers, who then adopt more EVs, bringing more station utilization and lower costs to charging providers. The long lead times for charging infrastructure build out and vehicle turnover, as well as the immediacy of the climate crisis, mean that there is no time to waste. We can and must begin making these changes immediately.

1 International Energy Agency. (2020). *Tracking Transport 2020*. **https://www.iea.org/reports/tracking-transport-2020**

2 Caiazzo, F., Ashok, A., Waitz, I. A., Yim, S. H., & Barrett, S. R. (2013). Air Pollution and Early Deaths in the United States. Part I: Quantifying the Impact of Major Sectors in 2005. *Atmospheric Environment*, 198-208.

3 International Energy Agency. (2019). *Transport Sector CO_2 Emissions by Mode in the Sustainable Development Scenario, 2000-2030*. **https://www.iea.org/data-and-statistics/charts/transport-sector-co2-emissions-by-mode-in-the-sustainable-development-scenario-2000-2030**

4 Jenn, A. (2019). *Emissions Benefits of Electric Vehicles in Uber and Lyft Services*. **https://escholarship.org/content/qt15s1h1kn/qt15s1h1kn.pdf?t=pw4rht**

5 Office of Energy Efficiency & Renewable Energy, US Department of Energy. *Charging at Home*. **https://www.energy.gov/eere/electricvehicles/charging-home#:~:text=Because%20residential%20charging%20is%20convenient,low%2C%20stable%20residential%20electricity%20rates**

6 International Council on Clean Transportation. (2020). *Charging Infrastructure Requirements to Support Electric Ride-Hailing in US Cities*. **https://theicct.org/publications/charging-infrastructure-electric-ride-hailing-us-032020**

7 US Energy Information Administration. (2020). *Gasoline and Diesel Fuel Update*. **https://www.eia.gov/petroleum/gasdiesel/**

8 AAA. (2019). *Your Driving Costs*. **https://www.aaa.com/AAA/common/AAR/files/AAA-Your-Driving-Costs.pdf**

9 Bloomberg New Energy Finance. (2020). *When Will Electric Vehicles Be Cheaper Than Conventional Vehicles?*

10 Schwartz, H. (2018). America's Aging Vehicles Delay Rate of Fleet Turnover. **http://energyfuse.org/americas-aging-vehicles-delay-rate-fleet-turnover/**

11 International Council on Clean Transportation. (2019). *Estimating Electric Vehicle Charging Infrastructure Costs Across Major US Metropolitan Areas*. **https://theicct.org/publications/charging-cost-US**

12 Muratori, M, Kontou E, Elgqvist, E, Cutler, D, Eichman, J. (2018). Electricity Cost for Electric Vehicle Fast Charging. **https://www.nrel.gov/docs/fy19osti/72326.pdf**

13 Uber. EVgo Fast Charging. **https://www.evgo.com/uber/**

14 International Council on Clean Transportation. (2019). *Emerging Policy Approaches to Electrify Ride-Hailing in the United States*. **https://theicct.org/publications/policy-briefing-electrify-ridehailing**