EV SHARED MOBILITY LITERATURE REVIEW AND STATE OF PLAY

Making the Business Case for Smart, Shared, and Sustainable Mobility Services

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Electrifying carshare and ride-hail services is a promising way to reduce greenhouse gas emissions from the transportation sector and help government achieve their climate change goals, according to recent literature. In addition, research shows better economics for ride-hail drivers could exist when the cost of charging is less than gasoline, and when charging is available and fast enough to not cut into their driving time. However, there remains an open question of if and how much carsharing and ride-hailing services can reduce travel overall, and therefore, greenhouse gas emissions. The barriers and solutions to deploying electric vehicles in shared mobility services is largely similar to those faced in the personal vehicle market. This state of play of shared mobility in the United States and literature review is a part of *Making the Business Case for Smart, Shared, and Sustainable Mobility*, a project which aims to accelerate the adoption of electric vehicles in shared mobility services and to establish best practices that can be used by others around the United States.

INTRODUCTION

Making the Business Case for Smart, Shared, and Sustainable Mobility (EV Shared Mobility for short) aims to accelerate the adoption of electric vehicles (EVs) in shared mobility applications and to establish best practices that can be used by other municipal and regional governments and businesses around the United States. The project, led by the City of Seattle and Atlas Public Policy, brings together the U.S. Department of Energy's Energy Efficient Mobility Systems program and major industry stakeholders with the cities of Seattle, New York, Denver, and partners in Portland to test different electric, shared mobility interventions. Visit www.evsharedmobility.org to learn more about the project.

Each project partner in the four cities will test a market intervention and then analyze the impact on EV adoption and electric vehicle miles traveled for either carshare or ride-hail services. A major part of the project is to share the results, successes, and lessons learned through these pilot programs. The project partners will not only facilitate the implementation of EVs and EV charging for the programs, but they will also evaluate the policies and programs that were employed during the project period.

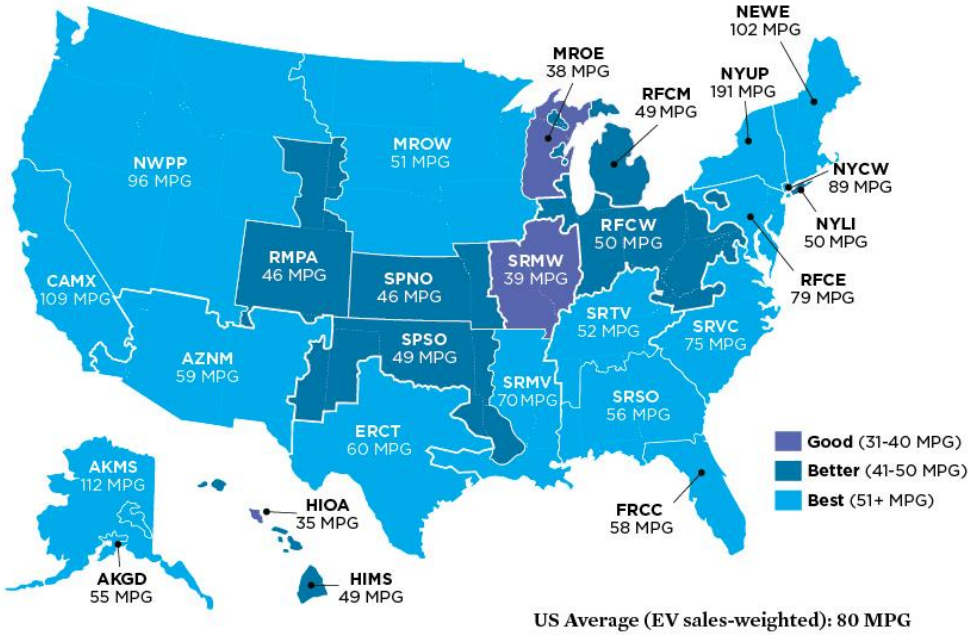
To inform the program development the project team assessed the state of play of EV shared mobility programs in the United States and researched publicly available literature on the electrification of shared use mobility services. Literature specifically on electrifying shared use mobility was not as prevalent as work done on transportation electrification and the impact of shared use mobility, separately. Therefore, this review pulls from those areas of the literature as well.

BACKGROUND

The transportation sector accounted for 27 percent of greenhouse gas (GHG) emissions in the United States in 2015 and of that, the light-duty vehicle (LDV) sector contributed 60 percent of those emissions [1]. Electrification presents an opportunity for reducing GHG emissions as a battery electric vehicle has approximately half the lifecycle emissions of a gasoline vehicle, depending on the fuel economy of the vehicle and the emissions from the electrical grid [2, 3]. In 2018, the Union of Concerned Scientists found

that throughout the United States, driving on electricity results in fewer lifecycle GHG emissions than driving a 35 mile per gallon (mpg) gasoline-powered vehicle; on average, EVs were found to be cleaner than a gasoline vehicle with 80 mpg, as shown in Figure 1 [3]. Reducing GHG emissions through the electrification of the transportation sector will help cities and states to achieve climate goals.

FIGURE 1: MILES PER GALLON EQUIVALENT RATINGS



Throughout the United States, driving on electricity is cleaner than driving a gasoline-powered vehicle. The miles per gallon equivalent for gasoline-powered vehicle is listed by region.

Source: Union of Concerned Scientists [3]

EV sales in the United States reflect a growing interest in electrifying the light-duty transportation sector. A 2018 survey by AAA found that one in five Americans say they are likely to buy an EV at some point in the future [4]. Since September 2015, there has been a streak of monthly sales records, with sales in each month in 2018 greater than in 2017 and 2016 [5]. If sales continue to grow, total EV sales could hit one million by the end of 2018.

States and cities are setting goals for EV adoption as a way of working towards achieving their climate goals. For example, participants in the EV Shared Mobility project are working toward the following EV goals:

- City of Seattle has a goal that 30 percent of all vehicles registered in the city will be electric by 2030 [6]. Additionally, the state of Washington has a goal to register 50,000 EVs by 2020 [7].
- In 2017, Mayor de Blasio announced a goal for New York City to have EVs comprise 20 percent of new vehicle registrations citywide by 2025 [8].
- Portland, Oregon is working to replace 10,000 gas- or diesel-powered vehicles with EVs by 2020 [9].

- In Denver, Mayor Hancock has set the goal that EVs make up 15 percent of vehicles by 2025, 30 percent of vehicles by 2030, and 100 percent of vehicles by 2050 [10]. Additionally, Colorado aims to grow its EV registrants to 940,000 in the state by 2030 [11].

As shared mobility grows in popularity [12, 13, 14], electrification in the shared use market will help cities and states to meet their EV adoption goals, and in turn can reduce the GHG emissions attributed to light-duty vehicles.

The EV Shared Mobility project will facilitate EVs being placed into shared use services with Maven Gig, a long-term vehicle rental program geared toward ride-hail and delivery drivers, offering up to 150 EVs in both New York City and Denver and an EV education and outreach program with ride-hail drivers in Portland. Additionally, significant charging infrastructure development in Seattle will support EVs in carshare and ride-hail platforms in the city, which will be done in coordination with its EV carshare partner, ReachNow. Although a small part of meeting the city and state goals, this project will pilot these concepts to inform future programs in the project cities and beyond.

Box 1. Why is Public Charging So Important to EV Shared Mobility?

The growing EV population will require charging infrastructure to help meet its charging demand [15]. Currently, a majority of EV drivers charge at home, but not all current or future EV drivers will have access to charging while parked at or near their home [16]. Some drivers, like carshare or ride-hail drivers, may require non-residential charging during a rental or active driving period [17].

In particular, conveniently located DC fast charging will play an important role in meeting the needs of EVs on ride-hailing platforms [18]. Even with over 6,700 publicly available DC fast charging ports in the United States, there is still a need to increase availability [18, 5]. Existing DC fast charging ports may be lacking in redundancy, interoperability, and future-proofing for faster charging capabilities, which means they may not always meet current EV needs or those of future long-range all-electric vehicles. The coming long-range EVs may require more charging opportunities outside of the home as they will be driven further distances for a wider variety of trips.

EV charging is being deployed through public-private partnerships, publicly-owned utilities, and unaided private sector investments. For example, New York City has committed to deploying 50 fast charging hubs across the city by 2020, a project that will be completed with both private partners and the electric utility [19]. Additionally, through a 2016 legal settlement, Volkswagen is required to invest $2 billion in zero emissions vehicle infrastructure and education programs in the United States, and is doing so through its established subsidiary, Electrify America [20]. The settlement requires that Volkswagen place another $2.9 billion in an environmental mitigation trust to be used by states to reduce mobile source emissions. Up to 15 percent of each state's mitigation trust funds, or more than $400 million nationwide, could be invested in light-duty charging infrastructure [20]. Electric utilities are also increasing their level of engagement, with the approval of $835 million in funding for charging infrastructure and other transportation electrification programs from nine utilities in 2018 alone [5].

Given how critical available charging is to electrification (see Box 1), one of the primary objectives of the EV Shared Mobility project is to test how making charging available to carshare and ride-hail electric vehicle drivers could impact EV use and the business case for providing publicly available charging services. The project partners will facilitate the deployment of more than 52 DC fast charging stations and

60 Level 2 charging stations across the partner cities. The charging stations will be placed in shared mobility hubs in Seattle to test the concept of co-locating transit and other modes of transport in central areas. In New York City and Denver, Maven Gig EV drivers will have access to free, dedicated (for one year) fast charging services provided by EVgo. In Portland, Portland General Electric and Pacific Power will both be installing "electric avenues" within their service territories.

SHARED USE MOBILITY POTENTIAL

The shared mobility market is large and encompasses bikesharing, carsharing, carpools, ride-hailing, shuttles, among other services. EV Shared Mobility focuses on testing interventions for carsharing and ride-hailing within the shared mobility market. Electrifying the high-mileage vehicles that operate these services can offer considerable environmental benefits that make it an attractive proposition.

To understand more about why these benefits exist, one must understand how these services operate. Carshare companies provide users access to a car for short-term use without the costs and responsibility of owning their own personal vehicle. Carshare companies offer multiple services, though this project focuses on two types: fixed parking and free-floating carshare. Fixed parking carshare services, like Zipcar or Maven, require users to pick-up and drop-off the vehicles at designated parking locations. Free-floating carshare services, like car2go and ReachNow, allow users to pick-up and drop-off vehicles at any location within a service area; vehicles can be driven outside of the service area, but must be dropped-off within a service area, often parking on the street.

Ride-hailing services, like Uber and Lyft, allow users to request a ride on-demand through a mobile application and specify their desired pick-up and drop-off locations. Ride-hail drivers either drive a personal vehicle or rent one for a daily or monthly fee through a service like Maven Gig or Lyft's Express Drive.

Multiple aspects of shared vehicle use support the case for the electrification of these vehicles, including:

- High mileage for ride-hail vehicles: Shared use ride-hail vehicles can travel thousands more miles per year than a typical personal vehicle. For example, New York City ride-hail drivers traveled on average 34,000 miles in 2016 [13]. The cost to charge an EV is often less expensive than the gasoline vehicle equivalent, especially when it is charged at low power, overnight [21]. Combined with relatively low maintenance costs, the total cost of EV ownership improves for high-use vehicles, so long as the cost of charging is low [17]. However, some public charging could be more expensive than the gasoline equivalent price. Carsharing EVs are unlikely to have the same high-mileage use as ride-hail vehicles. Using car2go as an example, in 2015, the carshare fleets in Seattle and Washington, DC had estimated annual VMTs of approximately 8,000 and 4,500 miles per vehicle, respectively [22, 23, 24].[1] These estimates are not only smaller than the ride-hail vehicles in New York City, but they are smaller than the average annual VMT for a light-duty vehicle in the United States, which is estimated to be 11,000 miles [25]. Switching from gasoline-powered vehicles to EVs regardless of VMT, however, still helps to reduce GHG emissions [17].
- Shared: Vehicles on these platforms are shared in different ways. Carshare services provide users access to a fleet of vehicles, which can eliminate the need for a personal vehicle and the

[1] Estimated VMT per vehicle used total annual VMT from the Martin & Shaheen (2017) reference and news stories that estimated the vehicle count to be 750 in Seattle and 800 in Washington, D.C.

associated costs and responsibilities of vehicle ownership. In ride-hailing, trips can be shared when riders use pooled services, which can greatly increase the efficiency of these transportation services and, along with electrification, are a core part of the ride-hailing providers' long-term vision for their platforms [26].

- Higher turnover rate: When looking at a fleet of vehicles, like a carshare service, greater use leads to a higher turnover than the personally-owned vehicle fleet and can accelerate the transition to newer, more affordable EVs [17]. This aspect of shared mobility is less applicable to ride-hailing drivers that drive their personal vehicles but could apply to rented vehicles used by ride-hailing drivers.

With these aspects of shared mobility in mind, a 2018 study from the Rocky Mountain Institute found that ride-hailing drivers are good candidates for EVs [21]. The study found that full-time drivers, those driving at least 50-hours per week, can save $5,200 per year in total vehicle expenses by driving an EV compared to a gasoline-powered vehicle [21]. More so, for those who choose to switch to an EV and drive less than 40 hours per week, total costs are lower if a ride-hail driver rents an EV compared to buying one [21]. Results of this study can help inform drivers considering EVs through the Maven Gig program, which is a vehicle rental program for ride-hail drivers through General Motors [27].

Although EV sales continue to rise and there is growing interest in electrification, use of EVs in shared mobility services is still uncommon. Many studies in this developing area of research looked at the impact of carshare and ride-hail services on the transportation sector, separately from electrification. They have found that increasing membership in carshare programs has the potential to reduce single-occupancy vehicle trips (SOV) and overall vehicle miles traveled (VMT) [14, 28]. A 2010 study on carsharing by the Mineta Transportation Institute found that the service resulted in fewer GHG emissions from the transportation sector; on an individual basis, however, the study found some carsharing could increase emissions for those who would not otherwise drive [29]. A more recent study from 2016 looked at car2go services in San Diego; Seattle; Washington, D.C.; Calgary, Alberta; and Vancouver, British Columbia and found similar results, with an overall reduction in household VMT and household GHG emissions amongst car2go users [22]. Considering that EVs have lower emissions than conventional vehicles, the reduction in VMT for carshare users could contribute to significant reductions in GHG emissions from electrified services compared to gasoline-powered ones [3].

The impact of ride-hail services on travel patterns and VMT is more uncertain. Most studies on shared mobility rely on self-reported surveys, which could skew the results if samples are not representative. The results of the studies also depend on the accurate self-reporting of the respondents. Studies from 2016 found that the same people using carshare or ride-hail also favor using public transit and are less likely to own personal vehicles. This could be because users of these services tend to live in urban environments. These 2016 studies did not determine conclusively if ride-hailing creates more vehicle miles traveled per user [30, 31].

A more recent study from the Transportation Research Board in 2018 looked again at the impact of ride-hailing services like Uber and Lyft on public transit and personal automobiles [32]. The authors found that there was no clear link between the use of ride-hail services at peak hours and changes to a region's public transit usage, and there was a decrease in vehicle ownership and SOV trips associated with ride-hail use among those who participated in the study [32]. This study indicated that shared use services can decrease car ownership and potentially vehicle miles traveled.

On the other hand, a survey of major cities in October 2017 found no relationship between vehicle ownership and the use of ride-hailing services. The same study found that although some users reduce

their miles driven in a personal vehicle by using ride-hailing apps, some of those miles are transferred to the ride-hailing vehicle [28].

To further complicate how ride-hailing services are evaluated, pooled, or shared trips on ride-hailing platforms present an opportunity to efficiently transport people and reduce the number of single-occupant rides, but research into the impacts are still being explored. The California Public Utilities Commission (CPUC) found in their study on ride-hailing services, that pooled rides on Uber contributed to approximately 11 million vehicle miles avoided by riders opting for shared trips, during the first half of 2016 [26]. However, the CPUC also stated that pooling of trips may not always reduce VMT, as some trips require detours from the most efficient route, which could add miles to a trip [26]. Overall, the CPUC acknowledged that pooling can be a valuable way to reduce VMT, assuming the algorithms to match rides work efficiently [26].

In summary, changes in VMT through the increased use of ride-hailing services is still unclear, but the potential to convert those miles from gasoline-powered to electric remains a promising way to reduce GHG emissions [3, 26].

OVERCOMING CHALLENGES TO EV SHARED MOBILITY

Even with great potential benefits, there are many challenges facing the electrification of carshare and ride-hail services. These electrification challenges are in some ways similar to the challenges for personal vehicle electrification including EV range, charging access, and awareness [15]. For example, range anxiety is a barrier for ride-hail drivers and regular EV drivers who need to know if they can complete their trip with the remaining battery charge. Access to charging near where their cars are located present issues for carshare companies and individual EV drivers; this challenge can be especially difficult to overcome for free-floating carshare companies. For ride-hail drivers, access to fast charging near where they drive is key to efficiently using an EV for the service as it is for EV drivers without reliable access to home charging. Finally, all drivers may not know that EVs are available or how they operate, which is why education and outreach is so important.

Solutions to drive the electrification of shared mobility can be similar to the personal vehicle market in some ways but will differ in charging and procurement strategies. In general, efforts to encourage EV adoption for personal use will largely benefit the electrification of shared mobility services. A study from the International Council on Clean Transportation (ICCT) found that EV market growth relies on the following, which could be in part applied to shared use vehicles [15]:

- the combined actions of many entities including local, state, and utility stakeholders;
- access to more EV models;
- consumer incentives even with declining costs of EVs; and
- all types of charging infrastructure development growing with EV uptake.

As evidenced in the ICCT study, lowering the upfront cost of purchasing an EV remains an important way to increase EV adoption by decreasing the cost differential between EVs and their gasoline counterparts. In shared mobility services with potentially higher mileage vehicles, there is the potential to make up for the high upfront costs of EVs with more vehicle use on a total cost of ownership basis so long as the cost of charging remains low relative to gasoline [17]. Federal and state EV purchase incentives exist to help to overcome this barrier, for personal use EVs and potentially within the shared use mobility market and are

found to be a critical component to EV uptake [15]. The federal tax credit is up to $7,500 and state credits range from $1,750 to $5,000 [15].

Additional options exist for ride-hail drivers to overcome the high upfront vehicle purchase costs, as drivers in some cities can rent an EV through a company like Maven Gig rather than having to purchase their own personal vehicle. This service eliminates the purchase cost, but drivers still pay a fee to rent the vehicle that cuts into their driving revenue. The Rocky Mountain Institute found that if a ride-hail driver wants to switch from a conventional vehicle to an EV, renting an EV might be best for those who drive less than 40 hours per week; in this case, the upfront costs of purchasing an EV was less likely to be made up through savings from reduced operating costs [21]. The study also noted that soon the used EV market will offer more affordable EV options for ride-hail drivers, which could lower the barrier of an EV purchase [21].

Carshare and ride-hail drivers may also have concerns about the range of EVs, like personal vehicle drivers. One solution to range anxiety is to have more EVs available with longer ranges, further emphasizing the need for expanded model availability [15]. Another way to address range anxiety is to have adequate and available charging, which is a major issue for the electrification of any vehicle. Also notable is the expected improvement in EV batteries that will increase range. The cost to power a vehicle with batteries has fallen over 70 percent since 2012; this decrease in cost is directly related to a change in the cost per mile of range for EVs on the market during that period.[2]

Charging infrastructure availability and speed of charging are critical to both carshare and ride-hail electrification [18, 22]. A previous effort by car2go to electrify carshare in San Diego found that availability of charging was important to maintaining an adequate utilization of the EVs and without adequate charging available it was difficult to keep the EV fleet charged [22]. For ride-hail drivers, time spent charging and not driving is potential revenue lost. Therefore, adequate charging availability, particularly fast charging, can help to alleviate range and availability stressors [18].

A study by the National Renewable Energy Laboratory (NREL) in 2018 focused on fast charging for EVs on ride-hail platforms [18]. The modeling completed for the study found that there was a notable increase in demand for DC fast charging with more EVs on ride-hail platforms, and that to improve the economics of building more charging stations, priority should be placed on high utilization areas over lower cost installations [18]. This is true for carshare as well, as EVs charging cannot be rented and the EVs may be parked anywhere in a service area (for free-floating carshare). Per the ICCT, overcoming the barriers to charging will require multiple avenues of investment, including public-private partnerships and electric utility engagement; a benchmark for an adequate number of charging stations is difficult to estimate as there is so much variety in charging availability on a local level [33].

Finally, education and outreach remain an important part of electrifying any sector of transportation, including shared use mobility and drivers unfamiliar with EVs, as many people lack basic knowledge about the technology and its use [15]. The ICCT found in their 2017 study that consumer education and outreach programs are common in a majority of the top 50 EV markets, including those that provide information on EVs (sometimes online) and those that host outreach events, like ride-and-drives [34].

Education and outreach programs should also be inclusive of underserved communities. A few studies looked specifically at education and outreach approaches to these communities within the shared use mobility and electrification contexts. A study by the Greenlining Institute from 2015, explained a detailed approach to carsharing education and outreach in underserved communities that may not have access to

[2] The cost per mile of electric range for the 2017 Chevy Bolt is 70 percent below the cost of the comparable 2012 Ford Focus Electric, according to official automaker websites.

shared mobility services, but could greatly benefit from electrified carshare [35]. The approach suggested making considerations for how outreach, cost structures, payment options, insurance, and locations of services might be different for an underserved community [35]. For local and state governments, for example, the study recommended the following outreach activities:

- Work with community-based organizations for outreach and to identify parking locations
- Provide information on carsharing, EVs, and charging
- Provide information on using carshare with other public transportation modes
- Develop carshare call centers that are combined with public transit call centers to connect mobility across both modes

The Greenlining Institute study also covered other topics for local and state governments to consider that would increase access to EV carsharing in underserved communities, including insurance deductible subsidization and alternative payment options. The study made suggestions on how carshare companies can better reach underserved communities, including similar recommendations about outreach, payment options, insurance, and technology [35].

The cities of Portland and Seattle both conducted outreach and education program research on transportation and EVs with underserved communities in their regions in 2017 and 2018, respectively [36, 37]. In Seattle, the outreach focused on EVs and shared mobility, and included listening sessions with underserved community members and immigrant and refugee residents in the area. In a summary report, the researchers found that EV knowledge was limited, but that the community members were interested in knowing more [36]. Building and maintaining partnerships within the community can help to continue the education and outreach process as more EV policies and programs are introduced into the region and will better ensure that there are no unintended consequences from new programs in these communities [36].

For the City of Portland, the focus was more on smart transportation and transit, in general. The researchers conducted focus groups and surveys within underserved communities. The study found that the people in these disadvantaged communities had lower vehicle ownership and tended to rely more heavily on other forms of transport, and that there are barriers to using smart technologies like a lack of access to driver's licenses or driver's cards, bank accounts, credit cards, and affordable cell and internet service [37]. The researchers found this outreach was an effective way to inform how smart transportation technology is implemented and received some recommendations through their survey and focus groups. Recommendations included: improve access to schedule and route information through smartphones; improve access to public WiFi; implement policies to make EV purchasing easier; and expand translation services [37].

STATE OF PLAY IN CITIES & PRIVATE PROGRAMS

Electrification of shared use mobility is gaining interest in major cities across the United States, including those participating in this project. City interest in the topic can be seen in the numerous related programs and policies that cities have put in place and a few EV and/or shared mobility action plans that have been published. For example, Los Angeles funded an electric carshare program pilot, BlueLA that serves disadvantaged communities and hopes to reach 7,000 households [38]. LA also plans to secure more funding for the electric carshare program with hopes of having 2,000 EVs by 2021 [38]. They are also testing out the concept of mobility hubs, which connect transit to other modes of transportation, which

includes providing charging at the mobility hub locations [39]. Below is a summary of activities in other cities:

- The City of Portland's strategy includes an effort to explore ways to increase electric shared mobility in carshare, ride-hail, and bike-share services through incentives [9].
- The City of Seattle is interested in how increasing EV use on new mobility platforms could reduce emissions from the transportation sector and have plans for increasing curbside charging and providing charging at mobility hubs [40].
- The City of Austin has a few initiatives it is supporting under its Smart Mobility Roadmap including deploying electric shared mobility resources and charging infrastructure in low income neighborhoods, increasing on-street fast charging, along with general EV awareness and incentive programs [41].
- The Twin Cities have a shared mobility action plan that focuses on reducing the number of cars on the roadways including supporting electric shared use vehicles and mobility networks [42].
- In August of 2018, New York City placed a 12-month moratorium on the issuance of new for-hire vehicle licenses to give the City time to assess the impact of for-hire vehicles on congestion, vision zero, and driver income [43].

Many cities are at the beginning of understanding how they can promote electrification in shared use mobility. As projects like EV Shared Mobility are completed, sharing knowledge gained through this project will be critical to developing and executing more initiatives across the country.

Within the private sector, there are a number of new programs and partnerships working to advance EVs in shared mobility services. In June 2018, Uber launched its EV Champions Initiative in seven cities across North America. This initiative builds off of pilots already underway in Pittsburgh and Portland [44] to provide monetary incentives to drivers using EVs in select markets, offer education to drivers on the benefits and other incentives available for EVs, provide in-app notifications to alleviate range anxiety of drivers, and promote shared rides. These incentives and educational efforts are in line with ICCT's findings on incentives and outreach [34], and are a promising way to encourage EV adoption among Uber drivers and help the company reach its goal of providing at least 5 million EV rides over the next year [44]. In Portland, the EV Shared Mobility team will expand Uber's education and outreach efforts by providing training, education, and promotional material to current and prospective EV drivers for ride-hailing services. The objective is for EV drivers in ride-hailing services to act as EV ambassadors to the riders, providing information and answering questions about EVs during the trip.

The private sector has also been testing out solutions to charging availability and incentives to promote electrification in the shared mobility market. Maven and EVgo have a joint effort that allows Maven EV drivers to use EVgo charging for free, for now, while renting a Maven EV [27, 45]. Maven Gig EV drivers can rent a Chevrolet Bolt for 28 to 35 days, depending on the location, by paying a weekly rate that includes unlimited miles and covers insurance and maintenance. The Maven-EVgo partnership was piloted in a few California cities and is expanding to others across the country as more EVs are added to the Maven platform. In April of 2018, EVgo and Maven announced that EVgo will be building a dedicated fast charging network for Maven [45]. This approach provides a solution to the issues of both high upfront EV ownership costs (rental through Maven) and charging (access to free, dedicated charging). The collaboration will be expanded to New York City and Denver through the EV Shared Mobility project. The 150 EVs on the Maven Gig platform in each city will have access to free and dedicated fast charging for one year through EVgo.

Other electric carshare programs that are active in the United States include BlueIndy in Indianapolis, an all-electric fixed parking program, BlueLA in Los Angeles mentioned previously, and ReachNow in Portland

and Seattle, a free-floating program that is not exclusively EVs [46]. Car2go previously operated a fully electric vehicle fleet in San Diego, but the program was ended when the expected charging infrastructure did not materialize [22]. More details on previous electrification programs will be shared through the EV Shared Mobility Case Studies.

CONCLUSION

Research into electrifying shared mobility services is an ongoing area of study. Interest in this space comes from the potential to reduce GHG and other emissions and improve the economics of these services by converting the gasoline-driven miles in carshare and ride-hail to electric miles. The potential to reduce emissions is supported by multiple studies. Switching personal or shared-use vehicles from gasoline-powered to electric drive will reduce lifecycle GHG emissions from the transportation sector, especially when those vehicles are used in high mileage applications; on average, EVs were found to be cleaner than an 80-mpg gasoline vehicle [3]. However, studies show the direction and magnitude of change in personal or household VMT from shared use services remains uncertain.

The lack of real-world data makes it difficult to accurately assess the long-term impacts of shared mobility services and what approaches to electrify these services may be successful. Generally, carshare is thought to reduce VMT for users, but the change in VMT for ride-hail users is still uncertain, as their interaction with other modes of transportation is more complex than carsharing.

Making the economic case for introducing EVs onto shared use platforms is complicated. The high upfront costs of an EV can be a challenge for all potential EV drivers. An EV could be competitive with a gasoline vehicle, especially for high-use vehicles, when looking at the total cost of ownership so long as the cost of charging is less than the gasoline equivalent. For ride-hail drivers, the economics are best when the cost of charging is low, and when charging is available and fast enough to not cut into their driving time. For carshare companies, low cost charging is critical to making the business case, but it is also important to a maintain high utilization for the vehicles in the fleet. This is especially challenging for free-floating carshares whose vehicles can be parked anywhere within a service area. Therefore, having convenient and adequate charging available is critical to the success of an EV carshare service.

Barriers to the adoption of EVs for shared use mobility services include vehicle range, charging, and education, and are similar to those barriers facing the adoption of EVs in the personal vehicle market. Solutions to the barriers can include incentives, education and outreach, and improved charging availability. Unique to the shared use market, however, are the efforts that private companies can take, including Uber offering EV driver incentives and helpful in-app additions, and Maven and EVgo working together to offer EVs to ride-hail drivers paired with fast charging services.

Interventions for the EV Shared Mobility project were informed by the private companies' efforts and literature on overcoming barriers through charging expansion and conducting education and outreach. The project team will explore the following:

- In New York City and Denver, the project partners will test offering EVs on the Maven Gig platform for ride-hail drivers paired with free, dedicated fast charging through EVgo.
- In Seattle, the project partners will deploy charging stations in shared mobility hubs to test the concept of co-locating transit and other modes of transport in central areas to support shared mobility services.

- Forth, in Portland, with project partners will support an EV education and outreach program with ride-hail drivers.
- The project team will evaluate the business case for electrifying these services by creating the EV Shared Mobility Analysis Tool to help government and companies evaluate the electrification potential in metropolitan regions.

The EV Shared Mobility project will expand the body of knowledge on the electrification of shared use mobility services and aims to document real-world experiences and produce data and further guidance currently lacking in the literature.

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