Chapter 1: Vehicle Electrification in Carsharing and Transportation Network Company (TNC) Fleets: Current and Future Trends

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This chapter focuses on two shared mobility modes - carsharing and transportation network companies (TNCs, also known as ridesourcing and ride-hailing) - and how they can incorporate electric vehicles (EVs) into their fleets. Shared mobility is the shared use of a vehicle, scooter, bicycle, or other travel mode; it provides users with short-term access to a travel mode on an as-needed basis. Carsharing (e.g., Zipcar, car2go) offers members access to vehicles by joining an organization that provides and maintains a fleet of cars and/or light trucks. Vehicles may be located throughout a city or region, and members who join a carsharing organization typically pay a fee each time they use a vehicle. TNCs (e.g., Lyft, Uber) are prearranged and an on-demand transportation service for compensation in which drivers and passengers connect via digital applications. Shared fleets have the potential to reduce vehicle ownership and vehicle miles/kilometers traveled (VMT/VKT), while increasing access to transportation options; whether their fleets are electric or not will affect how shared mobility services impact greenhouse gas (GHG) emissions. In this chapter, we consider emerging transportation business models and investment decisions that are intertwined with the transportation electrification process. Next, we address challenges and opportunities with privately operated electric fleets, as well as selected policies that seek to promote EVs in shared fleets. Finally, we apply this information to future scenarios, addressing how sharing, automation, and electrification trends align.

1. State of the Market

1.1. *Business Models and Development*

Spurred by increasing environmental awareness and economic concerns among the public, the "sharing economy" has quickly taken root as a strategy for increasing access to resources and saving money.[1] In the sharing economy, goods and services are either borrowed or rented on a short-term basis, as opposed to owning them. Assets, such as personal cars or bicycles, can be used on a shared, as-needed basis either among peers or through businesses. For assets with high capital costs, such as a vehicle, access to a shared good/service on an as-needed basis can provide a more affordable option. Rapid developments in communication and information technology have made sharing possible at scale, facilitating the sharing of assets among users and allowing for on-demand service growth.[2,3]

One of the sectors in which the sharing economy has rapidly taken hold is the transportation sector. Shared mobility--defined as the shared use of a vehicle, bicycle, or other low-speed travel mode--enables users to have short-term access to different transportation modes.[1] The term shared mobility is inclusive of carsharing, bikesharing, scooter sharing, ridesharing, public transit services, on-demand ride services, and microtransit. Courier network services can also be included as a form of shared mobility.[1] In this book chapter, we focus on two subsets of shared mobility, carsharing and TNCs, and the incorporation of EVs into their fleets.

In carsharing, individuals typically join an organization that maintains a fleet of cars and light trucks deployed throughout a geographic region. Vehicles can be located in neighborhoods or deployed near centers of business, public transit centers, or universities. The carsharing organization typically provides insurance, gasoline, parking, and maintenance. Members who join a carsharing organization typically pay a fee each time they use a vehicle.[1] There are four types of carsharing: roundtrip carsharing, one-way carsharing, peer-to-peer (P2P) carsharing, and fractional ownership. Definitions of each type of carsharing service follow.

- **Roundtrip:** A form of business to consumer (B2C) carsharing, members are required to return the vehicle to a designated parking space to complete a reservation.[3]
- **One-way:** A form of B2C carsharing, members pick up a vehicle at one location and can drop it off at another location.[1]
- **Peer-to-peer (P2P):** Individuals access a privately-owned vehicle through a third-party operator.[3]
- **Fractional ownership:** Individuals co-lease or subscribe to a vehicle that is owned by a third party. Individuals have "rights" to the shared vehicle but must take on a portion of the operating and maintenance expenses. The agreement can be facilitated through a dealership or a carsharing operator.[1]

TNCs provide on-demand transportation services by connecting passengers and drivers, usually through a smartphone application. The drivers use their own private vehicles. Booking, rating, and payment are made through the smartphone application.[1] "Ridesplitting" is a type of TNC service in which passengers can book a shared ride with other users who may have a similar route. Requests along a route can be booked in real time, which allows for dynamic route changes.[1] Ridesplitting services do not always result in a shared ride, as no other passengers may request a convenient tandem route.

1.1.1. *Carsharing Impacts to Date*

As of October 2016, B2C carsharing services were operating in 46 countries and six continents, with approximately 15 million members sharing approximately 157,000 vehicles. Of the B2C carsharing services, one-way carsharing accounted for 30.8% of global memberships and roundtrip carsharing accounted for 69% of global membership.[4] These numbers are not inclusive of other types of carsharing services, such as fractional ownership and P2P carsharing.

The environmental, behavioral, and economic impacts of carsharing services have been well studied; however, the magnitude of impact varies. Variations in measured impacts can be due to geographic- specific factors (i.e., different impacts based on land use and the built environment) and the method for measuring impacts. Studies vary in the number of vehicles shed and delayed auto purchases. An early look at the impact of roundtrip carsharing on North American household vehicle holdings found that approximately 9 to 13 vehicles are taken off the road for each carsharing vehicle, through either shed or postponed vehicle purchases.[5] A 2015 review by Greenblatt and Shaheen[6] found that most studies and member survey results released by U.S. and Canadian carsharing organizations show that 15 to 32% of carsharing members sold their vehicles. The percentage of members avoiding auto purchases varied from 25 to 71%.

Studies also differ on whether carsharing increases or decreases public transit ridership.[6] A survey administered to P2P carsharing members in 2014 found a similar number of respondents reporting an increase and decrease of bus and rail use; however, the vast majority of respondents reported no change.[7] A potential concern for public policymakers is the possibility that increased convenience and accessibility through carsharing will lead to a net increase in the number of trips. The same P2P study found that the number of driving trips increased among users (although the difference was small among the most active users).[7] Similarly, a 2015 study of the B2C carsharing market found that while one in seven respondents commuted to work less by private car, car use for non-commuting business purposes may increase overall.[8]

1.1.2. *TNC Impacts to Date*

Peer-reviewed literature on TNCs and ridesplitting impacts are limited, and the magnitude of impacts found vary across existing studies. This variation is likely due to different sampling techniques, survey questions used to gauge impact, temporal dimensions, and geographic specific features. In a recent study, Shaheen et al.[9] reviewed numerous studies that evaluated TNC impacts. Each study varied in the method of data collection (such as online survey, intercept survey, activity data, or vehicle location data) as well as the location; some studies were multi-city while others were highly localized.

Several studies examined the influence of TNCs on vehicle ownership and use (Table 1). Hampshire et al.[10] is a reverse of the typical impact study – it examines the impact of a disruption in TNC services, specifically, the suspension of Uber and Lyft in Austin in 2016.

Table 1. Impacts of TNCs on Vehicle Ownership

Publication	**Rayle et al., 2016[11]**	**Hampshire et al., 2016[10]**	**Clewlow & Mishra, 2017[12]**
Location	San Francisco, CA	Austin, TX	Seven Major Metropolitan Areas
Impact on Vehicle Ownership	TNC had no impact on vehicle ownership	8.9% of former TNC users purchased a vehicle after service disruption – suggests TNCs may postpone vehicle purchases	9% vehicle shedding rate among TNC users

Examining mode replacement, high variation exists among studies, especially among the impact on public transit and personal vehicle use. Table 2 presents the survey findings regarding modal substitution among TNC users. Note that the study in Austin[10] examines mode substitution after TNC services have been removed from a city, while the other studies examine the modes that TNC services replace. Overall, the results of mode replacement indicate that TNC impacts on other transportation modes are highly localized. Several of the studies in Table 2 indicate that TNCs induce demand, i.e., TNCs creates trips that otherwise would not have taken place.

Table 2. Modal Substitution due to TNCs

Publication	Location	Public Transit	Taxi	Personal Vehicle	Walk-ing	Bicycle	Induced Demand	Other
Rayle et al., 2016[11]	San Francisco, CA	33%	39%	6%	8%	2%	8%	12% (includes other TNCs, carsharing, and getting a ride with family/friends
Hampshire et al., 2016[1]	Austin, TX	3%	2%	45%	1%	2%	-	41% other TNCs; 4% carsharing
Henao, 2016[13]	Denver and Boulder, CO	22%	10%	28%	12%	Include d with walking	12%	5% other TNCs; 9% carpool
Feigon and Murphy, 2016[14]	Seven U.S. Cities	14%	8%	34%	6%	11%	1%	24% carsharing
Clewlow and Mishra, 2017[12]	Seven Major Metro Areas	15%	1%	21%	17%	7%	-	18% carpool
Gehrke et al., 2018[15]	Boston Metro Area, MA	42%	22%	18%	12%	-	5%	-
Alemi et al., 2017[16]	California	12%[*] 27%[**]	56%[*] 45%[**]	38%[*] 38%[*]	12%[*] 25%[**]	Include d with walking	7%[*] 9%[*]	5%[*] and 7%[**] would have used a van/shuttle service; 20%[*] and 32%[**] would have gotten a ride from someone else
Circella et al., 2018[17]	California	13%[+] 34%[++]	48%[+] 51%[++]	42%[+] 36%[++]	1%[+] 1%[++]	Include d with walking	6%[+] 8%[++]	8%[+] and 3%[++] would have used a van/shuttle service; 29%[+] and 22%[++] would have gotten a ride from someone else

[*] Gen X users
[**]Millenial users
[+] Non-frequent users
[++]Frequent users

Few studies have examined TNC vehicle occupancies.[18] A study by Rayle et al.,[11] conducted before the introduction of pooled services, found that half of TNC trips had more than one passenger, and the average number of passengers per trip was 2.1. A second study by Gehrke et al.,[15] found that pooled services represented approximately one fifth of the total TNC trips among the survey respondents. However, the study did not consider the match rates among shared rides (i.e., if a pooled ride shared more than one booking at a time) and the associated occupancy levels with matched and unmatched rides.

A significant limitation to evaluating TNC impacts is the lack of available operator activity data; most studies examined as of December 2018 did not include operator activity data in their impact analysis, with the majority relying upon self-reported survey data.[9, 18]

1.1.3. *Projected Electric Fleet Impacts*

As of 2016, estimates indicate that shared and nonshared commercial fleets account for 30% of the market for new EVs.[19] Shared mobility and the electrification of the transportation sector represent an exciting turning point for mobility, with the potential to reduce individual VMT/VKT and the carbon intensity of transportation. Vehicle electrification opens the opportunity to diversify the type of primary energy used to power vehicles. Rather than depending on crude oil, EV fleets can be powered by electricity generated from renewable energy or other low-carbon sources. However, large-scale EV deployment presents challenges to match power supply and demand, and EV charging could potentially exacerbate the challenges of peak-load demand.[20] Care should be taken to manage charging, expand upon grid capacity and power generation, and integrate load management strategies.

Table 3 provides a summary of the current literature modeling the expected environmental impacts of large-scale EV deployment.

Table 3. Impacts of Shared, Automated, and Electric Vehicles (SAEVs)

Publication	Methods	Expected Impacts
Greenblatt & Saxena, 2015[21]	Estimated per-mile GHG emissions of a fleet of shared, automated electric vehicles (SAEVs)	• SAEV fleet emissions expected to be 87 to 94% lower than a fleet of 2014 conventional gasoline vehicles SAEV fleet emissions expected to be 63 to 82% lower than a fleet of projected 2030 HEVs
Chen et al., 2016[22]	Modeled management of a fleet of SAEVs under various charging infrastructure and vehicle range scenarios	• Fleet size is dependent upon battery recharge time and vehicle range An 80-mile range SAEV could replace 3.7 privately owned vehicles • A 200-mile range SAEV could replace 5.5 privately owned vehicles • Faster charging equipment could increase vehicle shedding
Biondi et al., 2016[19]	Optimized parking location and capacity for a carsharing service with an EV fleet	• Most charging stations would require less than four spots • Only a few large charging stations (up to 15 spots) are needed to be placed in areas of high turnover • Possible impact on peak electricity demand can be mitigated by using fast-charging technologies

1.1.4. *The EV Market*

The EV market is rapidly growing. In 2017, the global EV market reached 1.2 million units sold, with more than 165 models available for purchase. Based on manufacturer commitments, 25 million EV units are expected to be sold by 2025.[23] Global EV sales were around 1.3% in 2017, up from 0.8% in 2016.[24] Currently, battery electric vehicles (BEVs) make up 66% of the global EV market, and BEV sales are expected to grow more rapidly than plug-in hybrid electric vehicle (PHEV) sales.[24] China has the largest EV market (larger than the US and Europe combined); however, only Norway has reached critical mass for EV adoption. As of December 2017, every second car sold in Norway was an EV.[24] While the market for EVs is growing rapidly, market growth is limited by insufficient charging infrastructure. Not surprisingly, charging infrastructure tends to be denser in regions where EV sales are highest.[23] The following list includes a sample of EV manufacturing commitments.

- Hyundai, Kia: Will offer PHEV, EV, and hybrid models of their new vehicles.[25]
- Jaguar Land Rover: Plans to make only electric and hybrid vehicles by 2020.[26]
- Renault Nissan & Mitsubishi Alliance: Will offer 12 new EVs by 2022.[26]
- Porsche: Plans to make 50% of its vehicles electric by 2023.[26]
- General Motors, Toyota, Volvo: Companies target one million EV sales by 2025.[26]
- BMW: Will offer 12 fully electric models by 2025.[26]
- Volkswagen: Plans to produce 50 fully electric models by 2025.[25]
- Aston Martin: Expects to have 25% EV sales by 2030, with its remaining line consisting of hybrids.[26]

2. Challenges and opportunities

2.1. *Challenges*

The use of EVs in shared fleets faces many challenges: operational (i.e., the cost and logistics of operating an electric fleet, maintaining charging infrastructure, etc.); political (i.e., how to implement sustainable policies and protect consumer privacy); and behavioral (i.e., lack of exposure, range anxiety, and lack of incentives). This section outlines the challenges facing widespread EV deployment in shared fleets. Opportunities for addressing these challenges are discussed in the following section.

2.1.1. *Operational Challenges for Carsharing Services*

Shared mobility operators must first address the higher up-front cost of using EVs within their fleet. EVs are more expensive to purchase than conventional vehicles, putting the operator at risk if ridership is lower than expected. However, EVs have lower maintenance costs due to the lower number of moving parts and regenerative braking systems.

Operational challenges associated with carsharing fleets include:

(1) ensuring sufficient vehicle charge for trip completion, (2) maintaining a well-distributed fleet over service area, and (3) balancing fleet size with relocation staff size. To ensure users encounter vehicles with sufficient battery charge to complete their trip, operators must consider the trade-off between the cost of installing long-term infrastructure (such as charging stations) and the cost of day-to-day operations.[27] For example, it may be more cost effective to install additional charging stations, if it means reducing the need for vehicle relocation operations. Shared fleet operators must also consider charging infrastructure location design, such as placing more charging spaces at locations with high vehicle turnover or using a mix of slow- and fast-charging stations.

Maintaining a well-distributed fleet is crucial to operations. If a customer has difficulty finding a vehicle or must walk away due to insufficient power levels, the experience could have a long-term effect on their perception of the service and willingness to use it in the future. There are several strategies to maintain a well-distributed fleet: vehicle rebalancing, imposing parking reservation policies, and balancing station capacities.[28] EV fleets make vehicle rebalancing more difficult and costly due to limited infrastructure and long charging time.[29] Carsharing operators must be careful to ensure that users can find vehicles nearby that are sufficiently charged. Vehicle rebalancing involves logistical challenges, such as the tradeoff between designing fleet size and staff size for relocations. A larger fleet means fewer relocations and thus fewer staff are needed, while a smaller fleet typically involves more extensive vehicle relocation operations.[28] Likewise, the use of EVs in fleets necessitates familiarity with EV maintenance and operations among staff, perhaps requiring staff retraining.

The deployment of EVs in shared fleets has had a few bumps: the closure of Autolib' in Paris[30] and car2go's switch from an all-electric fleet to a gasoline fleet in San Diego, CA.[31] Both cases offer insights into the sustainability of a shared EV fleet business model. Autolib', which was at one point the largest one-way carsharing service in the world, was an electric carsharing service in Paris. The company's revenue model was based on a mixture of yearly subscriptions and charging per trip.[30] After the company announced an expected deficit of around 300 million Euros,[32] Paris immediately canceled the company's contract. The deficit was attributed to falling trip numbers and subscribers. The reduction in trips and subscribers has been attributed to multiple factors including: poor vehicle maintenance, rapid success (leading to not enough vehicles for customers and a drop in subscribers), and the growth of competing on- demand mobility services, such as TNCs.[32] Additional speculation is that the cost of relocating vehicles for such a large service grew too expensive, and a public service contract with the city made it impossible to close unprofitable stations.[30] Meanwhile, the failure of car2go's electric fleet in San Diego was attributed to insufficient charging infrastructure, leading to a shrinking customer base and worries about charging anxiety. The company was promised 1,000 charging stations to be installed in San Diego by the federal government, but the number shrunk to 400 after the nonprofit handling the installations went bankrupt.[31]

2.1.2. *Operational Challenges for TNC Services*

TNC companies are making efforts to deploy EVs within their fleets; however, many barriers exist to EV use in these services. As drivers on these platforms are responsible for vehicle-related expenses, any higher expenses due to EV ownership fall upon the drivers (as opposed to carsharing in which the operator assumes vehicle-related expenses). Some benefits exist to EV use by TNCs – vehicle maintenance costs are lower due to fewer moving parts, making the vehicles especially attractive for high-mileage use cases. Fuel costs can be lower; for example, one study of 2017 data in California found vehicle charging costs to be almost half as much as fuel costs for conventional vehicles.[33]

However, the higher EV purchase price prevents many drivers from actualizing the lower vehicle maintenance costs. If drivers are not turned away by the sticker price, they often have difficulty financing an EV. Banks are typically unwilling to lend to TNC drivers due to faster vehicle depreciation. In addition, full-time drivers may lack a stable income.[33] In regard to operation, drivers may not be able to actualize the lower fuel costs associated with EVs, as many drivers do not have home charging and must rely on public fast-charging stations, which can be prohibitively expensive.[33] Another barrier to entry is the earning potential lost due to the need for charging; drivers must search for charging stations, possibly wait for access and then spend time charging their vehicle.[33] Finally, the nature of TNC platforms creates many logistical challenges: platforms often do not let the driver know the trip length or final destination of their passengers before accepting rides to prevent discrimination, meaning drivers lack flexibility to plan around their charging needs.[33] Drivers may also be penalized for this lack of flexibility. For example, if a driver needs to decline a trip because the destination is too far from a charging station, it may damage their ratings on the app platform.

2.1.3. *Infrastructure Uncertainties*

The impact of widespread EV deployment upon the power grid depends heavily on charging management. For example, the charging strategies deployed could alter whether further infrastructure investment is needed. There are several types of "charge plans," including:

- **Simple or unconstrained charging** in which the vehicle immediately begins charging as soon as it is connected to the grid;

- **Delayed charging** in which battery charging is offset by a set amount of time (i.e., vehicle delays charging until nighttime); and
- **Smart charging** in which a utility or system operator has some measure of intelligent control over vehicle charging. This can be through direct vehicle control or by designing the EV to respond to price signals.[34]

The type of charging strategy deployed by shared fleet operators will determine the impact on the electric grid. A review of the literature on the impacts of EV charging on the power grid[34] found that peak loads are expected to increase under simple charging strategies (thus requiring additional generation and transmission capacity), while smart charging strategies have the potential to level demand and make use of excess generation (thus requiring no additional infrastructure investment). In addition to charging behavior, EVs have a negative impact on the grid distribution. Due to their nonlinear nature, battery chargers can produce harmonic effects on the electric distribution system[35], which in turn increase losses in electrical equipment and power distribution[36]. EV charging can also be detrimental to transformer lifespans[35] and potentially cause transmission bottlenecks and increased line losses.[34]

EVs themselves are vulnerable to infrastructure uncertainty; challenges include the possibility of insufficient power capacity or power quality problems whose effects can include interruption of process, equipment damage, loss of important data, or malfunctioning of protective devices.[36] Certain charging strategies, such as demand-response programs, offer opportunities to minimize infrastructure uncertainty. Demand- response programs, however, face their own barriers to implementation, such as customer concerns over privacy (utilities or third parties might need control of vehicle charging) or system errors. Shared mobility operators or vehicle owners may be unwilling to cede control of EV charging.

2.1.4. *Policy Challenges*

A wide array of incentives and regulatory actions have been applied to promote the growth of the EV market, yet uncertainty exists on the most effective policies for influencing EV adoption rates. In the U.S., some states with higher than national average purchasing incentives see market shares 3 to 4% higher than the national average, while other states with similar incentives struggle to grow EV deployment.[37] More studies are needed on the mix of direct and indirect incentives and regulatory actions needed to promote the EV use in shared fleet. Examples of policies are explored in a later section: *Policy Opportunities*. Governments also face challenges in funding incentive programs – should funds be generated from TNCs themselves by adding surcharges to rides or should funds be pulled from other initiatives, such as cap-and-trade programs?[33] Equity concerns exist with using governmental funds to promote EV deployment within fleets, as the incentives will not necessarily extend to the broader pool of EV drivers (i.e., individuals who privately own EVs).[33] Data sharing, which can help governments identify emerging patterns in electric fleet activity and assist in decision making, faces privacy concerns from riders and reluctance from operators.[38]

2.1.5. *Behavioral Challenges*

Our literature review on the topic of EVs found that consumer awareness of EVs is low. The lack of awareness touches upon a lack of familiarity with technology (such as how the vehicles perform and are charged), a lack of knowledge about incentive programs and vehicle models, and misperceptions of the savings that can be realized from lower fuel and maintenance costs. A 2013 study of 21 large cities in the US found that two-thirds of respondents could not answer basic factual questions about EVs, and approximately 95% of respondents were unaware of state and local incentives designed to promote EV purchases.[40] Increasing awareness of consumers is an important barrier to address, as current research indicates that consumers with greater experience with EVs are more likely to consider purchasing EVs and may pay more for the technology.[39]

2.2. *Opportunities*

Shared mobility services, such as carsharing and TNCs, offer the opportunity to experience an EV without making a personal investment. Given their limited range, EVs can be attractive for many forms of shared modes, which tend to provide mobility for short trips. For shared vehicles, EVs can often be parked at charging stations while waiting for the next user. A 2017 report by RethinkX[41] estimated that an EV fleet could cost almost half as much per-mile as a conventional vehicle fleet, primarily due to lower maintenance costs, lower depreciation rates, and fueling costs.

2.2.1. *Policy Opportunities*

Governments have many approaches to consider in promoting EV deployment in shared mobility. Examples include offering incentives for consumers or companies, investing in charging infrastructure networks, supporting regional planning activities, or engaging in educational outreach. Governments can also directly mandate the incorporation of EVs through regulatory actions. For a comprehensive review of policy approaches to encourage EV deployment in fleets, see the ICCT briefing on emerging policy approaches for electrification of TNC fleets[42] and Slowik & Lutsey's whitepaper on the growth of EVs in the US.[43] A few existing policies are highlighted below.

California California's Zero-Emission Vehicle (ZEV) regulation requires manufacturers to produce a specific number of ZEVs each year, based on the total number of cars sold in California by the manufacturer. ZEVs encompass BEVs, hydrogen fuel cell vehicles, and PHEVs. Manufacturers must earn a certain number of credits per year, and each vehicle earns credits based on the type of ZEV vehicle and its battery range. Estimates from the California Air Resources Board indicate that 8% of California new vehicle sales in 2025 will be ZEVs and plug-in electric hybrids.[44] While not specifically targeting fleet deployment, this policy aims to increase ZEV affordability and EV driving ranges, which would benefit TNC operators seeking to encourage EV ownership among drivers. In 2018, California approved SB 1014, which will set annual targets for GHG emissions per passenger-mile driven by TNCs by 2021 and reduce emissions below the baseline by 2023. The bill is intended to increase the number of ZEVs within TNC fleets.[45]

Colorado Through a public-private initiative, Clean Air Fleets, Colorado is offering incentives and educational programs to encourage fleet electrification. Both public and private fleets can apply for subsidies for EV purchases; fleets receive 80% of the incremental cost up to the cap. The cap is set at 3,000 USD for private, light-duty vehicles. The subsidies are funded by the Federal Highway Administration's Congestion Mitigation and Air Quality Improvement program as well as funds from the Volkswagen Diesel Emission Environmental MitigationTrust.[46]

China China has deployed a suite of policies and regulatory actions at all levels of government intended to encourage EV market growth. In 2009, China launched a national campaign, Ten Cities, Thousand Vehicles, in which participating cities qualified for substantial subsidies and preferential policies to develop their local EV markets. Policy actions directly related to encouraging EVs in fleets included the introduction of EV carsharing programs, taxi fleet purchase incentives, road access privilege (i.e., certain lanes or roads are only available to those with EVs), and group purchase subsidies. The government aims to have 5 million "new energy vehicles" on the road by 2020.[47]

2.2.2. *Educational Outreach*

There are several existing tools and databases available to shared mobility operators that are considering incorporating EVs into their fleets. One example of an educational tool is the U.S. Department of Energy's (U.S. DOE) Alternative Fuels Data Center, which maintains publicly available information, data, and tools on alternative fuels and advanced vehicles. The project provides several tools including: (1) an Alternative Fueling Station Locator, (2) a database of U.S. federal state laws and incentives,
(3) an EV emission calculator, and (4) a vehicle cost calculator.[48] These tools and further examples of information hubs are listed in Table 4.

Table 4. Tools and Info Hubs for EV Deployment

Tool/Info Hub	Source	Description
Alternative Fueling Station Locator	U.S. DOE Alternative Fuels Data Center	Database and map of alternative fueling stations in the U.S. and Canada. Users can filter by fuel/technology type, location, accessibility (public or private), and status of each station (available, planned, or temporarily unavailable).[48]
Federal and State Laws and Incentives	U.S. DOE Alternative Fuels Data Center	Database of U.S. federal and state laws and incentives for alternative fuels, vehicles, and other transportation-related topics. Users can search through database by topic and state.[48]
Emissions from Hybrid and Plug-In	U.S. DOE Alternative Fuels Data Center	Calculates the annual emissions per vehicle type (all electric, PHEV, HEV, and gasoline)

Electric Vehicles	depending on U.S. state electricity generation mix.[48]	
Vehicle Cost Calculator	U.S. DOE Alternative Fuels Data Center	Uses basic information about driving habits (annual mileage, percent trips by highway, etc.) and vehicle model to calculate the total ownership cost and emissions. Includes conventional vehicles and alternative fuel vehicles.[48]
Environmental Assessment of a Full Electric Transportation Portfolio	EPRI	A report that provides an analysis of the environmental impact of the electrification of a range of vehicles, from U.S. light-duty transportation to industrial equipment. Simulates emissions and air quality impacts associated with electrification.[49]
Open Charge Map	Open Charge Map (non-profit)	A free, public database of global charging equipment locations. Goal is to provide a single point of reference for charging equipment location information. Major data sources include: U.S. DOE, UK National Charge Point Registry, and Catalan Energy Institute, among others. Data can also be provided by users.[50]
EV Infrastructure Projection Tool	National Renewable Energy Laboratory, California Energy Commission	Developed to assist planning studies, the tool provides estimates of the quantity and type of charging infrastructure needed to support regional EV adoption. The tool uses data from personal vehicle travel patterns, EV attributes, and charging station characteristics. Recently, NREL released EV-Pro Lite, a simplified version of the full model that identifies existing public EV charging infrastructure and projects future consumer demand for charging infrastructure based on user inputs for the anticipated number of EVs.[51]

2.2.3. *Initiatives by Private Companies*

Whether motivated by environmental concern or anticipation of future regulations, shared mobility operators have made voluntary efforts to introduce EVs into their fleets. Many carsharing operators have introduced EVs into their services including Renault's electric fleet in Paris;[52] Zipcar in London;[53] and Maven in the U.S.[54] Due to indirect control over their fleets, TNCs have taken more creative approaches to electrification, listed in Table 5 below.

Table 5. EV Initiatives Among TNC Operators

Company	Location	Initiative
Didi Chuxing	China	In January 2019, Didi Chuxing announced a joint venture with a state-owned BEV manufacturer to work on projects related to TNCs, big data, battery swapping, and the operation of "new energy vehicles." Didi captured 90% of China's TNC trips in 2017.55 In general, Didi has been cultivating partnerships with car manufacturing and leasing companies to enable bulk procurement of EVs and charging infrastructure.[42]
Lyft	U.S.	Lyft launched its "Green Mode" initiative in February 2019. Users are able to choose a hybrid or EV for their ride rather than a conventional gasoline-powered vehicle. Lyft says it plans to introduce thousands of EVs through its driver rental program, Express Drive. Lyft drivers who participate pay less in rental fees and receive unlimited charging (included in the rental rate). The program has been deployed in Seattle and Portland and will spread to other areas of the U.S. throughout 2019.[56,57]
Maven	U.S.	Starting in 2017, Maven - a subsidiary of GM - began offering an EV rental service for on-demand drivers. For 229 USD a week, drivers can rent a Chevy Bolt through Maven Gig. The price includes insurance, maintenance, and charging. Maven has officially partnered with Uber, Lyft, GrubHub, Instacart, and Roadie for the program.[58]
Uber	London	After the City of London announced plans to require all private-hire vehicles to be zero emission capable by 2023, Uber launched an incentive pilot program from September 2016 to January 2017. Drivers were offered a £300 reward for switching to an EV, a £50 weekly participation reward, and a charging incentive. The program was funded partially by a £2 million investment and partially by a surcharge applied to non-pooled rides in London.[34] Starting in 2019, Uber adds a "clean air fee" of £0.15 per mile on trips booked in London. The money from the fee goes toward assisting drivers in switching to EVs. The company plans to transition every car in its London fleet to full electric by 2025.[59]
Uber	U.S. and Canada	In June 2018, Uber launched a year-long pilot program, "EV Canada Champions Initiative," which will take place in seven cities throughout the U.S. and Canada. Drivers are offered a financial incentive to switch to EVs, likely around 1 USD extra per ride. Uber also added features in its app specifically for EV drivers.[60]

Uber has called for policy measures that would support EV deployment in TNC fleets including: an increase in available charging stations and fast- charging equipment; enabling companies to route drivers to available charging stations, perhaps through real-time data that can be incorporated into routing algorithms; and providing amenities like bathrooms, food, and Wi-Fi at charging stations.[61]

3. Future Fleets

3.1. *SECA Fleet Transition*

Shared, electric, connected, and automated (SECA) vehicles are predicted to transform mobility. Transitioning to shared, automated EV fleets may reduce the number of accidents by removing human error as well as reduce environmental footprints by removing personal vehicles from the road and increasing shared mileage. Automation may relieve the challenges associated with fleet electrification: vehicles could rebalance themselves, drive to passengers, and locate and drive to available charging stations without human intervention. Expert predictions on the rate of automation vary; a report by Bloomberg found that a fully automated taxi fleet could become a reality between 2023 and 2030, while an ambitious projection by RethinkX predicted that by 2030, 95% of U.S. passenger miles will be served by on-demand automated EV-owned fleets.[9, 41]

The future success of shared EV fleets will rely not just on automation but also on technological developments for charging infrastructure and battery technology. Many of the operational challenges identified earlier in the chapter can be mitigated with emerging technologies. For example, blockchain-enabled charging can reduce range anxiety and expand the network of available charging stations by connecting EV drivers to available home stations. In the future, wireless charging may be incorporated into roadways, enabling charging on the move and extending vehicle ranges. Future technologies and their impact on EV fleets are further explored in Table 6 below.

Table 6. Future Technologies

Technology	Description	Potential for EV Fleets
Wireless Charging	Wireless charging uses an electromagnetic field to charge the EV, usually with an efficiency above 90%. No contact is need between the vehicle and charger. Wireless power transfer can be used in both stationary charging scenarios (i.e., when a car is above a charger) or in dynamic charging scenarios (i.e., while driving or moving, if charging infrastructure is built into roadways).[62]	• Enables automated charging of EV fleets; vehicles would simply need to park over charging pads • Dynamic charging may extend vehicle range, parked enabling more trips between charging events
Blockchain-Enabled Charging	Blockchain enables a decentralized ledger where financial transactions and smart contracts can be executed without intermediaries.[9] Several startups, such as eMotorWerks in California, have implemented blockchain to expand access to charging stations. EV owners can join a distributed, peer-to-peer (P2P) marketplace that allows drivers to pay each other for use of their home charging stations. Blockchain is used to track charging stations and exchange payment between customers and hosts.[63]	• Enables P2P use of charging stations, expanding the network of available charge points
Vehicle-to-Grid (V2G) Charging	Vehicle-to-grid (V2G) charging enables electric-drive vehicles (battery, fuel cell, or hybrid electric vehicles) to provide power to electric markets. In the short term, V2G technology can help provide peak power and serve as storage for renewable energy generation.[64]	• Incentivization of EV fleets; the vehicles could be used to support deployment of renewable energy and mitigate peak demand • Could receive charging discounts for providing power, offsetting charging costs for fleet owners
Solid-state Batteries	Instead of the liquid or polymer electrolytes used in other battery types, solid-state batteries rely on solid electrodes and solid electrolytes. Proponents of solid-state batteries believe they will lessen many of the safety risks and costs associated with lithium-ion batteries. Most experts believe commercial deployment of solid-state batteries is at least a decade away.[65]	• Potential for lower-cost batteries • May have longer battery range, enabling more trips between charging events

Fast Charging	Level 3 or DC Fast Charging is typically used for commercial and public charging stations. DC Fast Charging is meant to provide an experience similar to that of fueling a conventional vehicle with gasoline. Typically, fast charging stations can charge a vehicle up to 80% within 10 to 15 minutes. The costs of a DC Fast Charging station are estimated to be between 50,000 to 160,000 USD, depending on the quality and nature of the components.[66]	• Reduction in range anxiety • For carsharing fleets, can have fewer vehicles in fleet, if less time is spent charging • Minimizes interruptions in productive time for TNC drivers

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References

1. Cohen A, Shaheen S. Planning for Shared Mobility. 2018 Mar 1.
2. Cohen B, Kietzmann J. Ride on! Mobility business models for the sharing economy. Organization & Environment. 2014 Sep;27(3):279-96.
3. Shaheen S, Martin E, Bansal A. Peer-To-Peer (P2P) Carsharing: Understanding Early Markets, Social Dynamics, and Behavioral Impacts.
4. Shaheen S, Cohen A, Jaffee M. Innovative Mobility: Carsharing Outlook.
5. Martin E, Shaheen SA, Lidicker J. Impact of carsharing on household vehicle holdings: Results from North American shared-use vehicle survey. Transportation Research Record. 2010 Jan;2143(1):150-8.
6. Greenblatt JB, Shaheen S. Automated vehicles, on-demand mobility, and environmental impacts. Current sustainable/ renewable energy reports. 2015 Sep 1;2(3):74-81.
7. Shaheen S, Martin E, Bansal A. Peer-To-Peer (P2P) Carsharing: Understanding Early Markets, Social Dynamics, and Behavioral Impacts.
8. Clark M, Gifford K, Anable J, Le Vine S. Business-to-business carsharing: evidence from Britain of factors associated with employer-based carsharing membership and its impacts. Transportation. 2015 May 1;42(3):471-95.
9. Shaheen S, Totte H, Stocker A. Future of Mobility White Paper. Caltrans. 2018 Jan. Retrieved from: http://www.dot.ca.gov/hq/tpp/offices/osp/future-of-mobility.pdf
10. Hampshire R, Simek C, Fabusuyi T, Di X, Chen X. Measuring the Impact of an Unanticipated Disruption of Uber/Lyft in Austin, TX.
11. Rayle L, Dai D, Chan N, Cervero R, Shaheen S. Just a better taxi? A survey-based comparison of taxis, transit, and ridesourcing services in San Francisco. Transport Policy. 2016 Jan 1;45:168-78.
12. Clewlow RR, Mishra GS. Disruptive transportation: The adoption, utilization, and impacts of ride-hailing in the United States. University of California, Davis, Institute of Transportation Studies, Davis, CA, Research Report UCD-ITS-RR-17-07. 2017 Oct.
13. Henao A. Impacts of Ridesourcing-Lyft and Uber-on Transportation Including VMT, Mode Replacement, Parking, and Travel Behavior. University of Colorado at Denver; 2017.
14. Feigon S, Murphy C. Shared mobility and the transformation of public transit. 2016.
15. Gehrke S, Felix A, Reardon T. Fare choices: A survey of ride-hailing passengers in metro Boston. Metropolitan Area Planning Council. 2018.
16. Alemi F, Circella G, Handy S, Mokhtarian P. What influences travelers to use Uber? Exploring the factors affecting the adoption of on-demand ride services. 2017.
17. Circella G, Alemi F, Tiedeman K, Handy S, Mokhtarian P. The Adoption of Shared Mobility in California and Its Relationship with Other Components of Travel Behavior. 2018 Feb.
18. Shaheen S, Cohen A. Shared ride services in North America: definitions, impacts, and the future of pooling. Transport Reviews. 2018 Jul 11:1-6.

19. Biondi E, Boldrini C, Bruno R. The impact of regulated electric fleets on the power grid: The car sharing case. InResearch and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 2016 IEEE 2nd International Forum on 2016 Sep 7 (pp. 1-6). IEEE.
20. Hacker F, Harthan R, Matthes F, Zimmer W. Environmental impacts and impact on the electricity market of a large scale introduction of electric cars in Europe-Critical Review of Literature. ETC/ACC technical paper. 2009 Jul;4:56-90.
21. Greenblatt JB, Saxena S. Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles. Nature Climate Change. 2015 Sep;5(9):860.
22. Chen TD, Kockelman KM, Hanna JP. Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. Transportation Research Part A: Policy and Practice. 2016 Dec 31;94:243-54.
23. Frost & Sullivan. Global Electric Vehicle Market Outlook, 2018 [Internet]. Frost & Sullivan; 2018 Mar 27 [cited 2019 Jan 4]. Available from: http://www.frost.com/sublib/display-report.do?id=MDAB-01-00-00- 00&bdata=bnVsbEB %2BQEJhY2tAfkAxNTQ2NjI4NjEyMTUz
24. Hertzke P, Müller N, Schenk S. The global electric-vehicle market is amped up and on the rise [Internet]. McKinsey&Company; 2018 May [cited 2019 Jan 4]. Available from: https://www.mckinsey.com/industries/automotive-and-assembly/our- insights/the-global-electric-vehicle-market-is-amped-up-and-on-the-rise
25. Bellan R. The Grim State of Electric Vehicle Adoption in the U.S. [Internet]. CityLab; 2018 Oct 15 [cited 2019 Jan 4] Available from: https://www.citylab.com/transportation/2018/10/where-americas-charge-towards- electric-vehicles-stands-today/572857/
26. Singh S. Global Electric Vehicle Market Looks to Power Up in 2018 [Internet]. Forbes; 2018 Apr 3 [cited 2019 Jan 4]. Available from: https://www.forbes.com/sites/sarwantsingh/2018/04/03/global-electric-vehicle- market-looks-to-fire-on-all-motors-in-2018/#71b6642c2927
27. Zhao D, Li X, Zhang Y. Electric Vehicle Sharing Planning and Operations. Center for Transportation, Environment, and Community Health. 2018 February 1. Available from: https://cpb-us-w2.wpmucdn.com/sites.coecis.cornell.edu/dist/6/132/files/2017/11/USF_YR1_LI- ZHANG_FINAL_ELECTRICAL-VEHICLE-SHARING-2hi9qf1.pdf
28. Nourinejad M, Zhu S, Bahrami S, Roorda MJ. Vehicle relocation and staff rebalancing in one-way carsharing systems. Transportation Research Part E: Logistics and Transportation Review. 2015 Sep 1;81:98-113.
29. Chow J. Dual Rebalancing Strategies for Electric Vehicle Carsharing Operations [Internet]. C2SMART; 2018 [Cited 2019 Jan 14]. Available from: http://c2smart.engineering.nyu.edu/2018/05/11/dual-rebalancing-strategies-for- electric-vehicle-carsharing-operations/#1518033148087-355212d9-bd9e2670-5054
30. Matlack, C. and A. Nussbaum. Now Paris Has Pulled the Plug on Its Electric Car- Sharing Service. [Interet]. Bloomberg; 2018 [Cited 2019 Jan 14]. Available from: https://www.bloomberg.com/news/articles/2018-06-22/once-a-trailblazer-paris-is- now-mopping-up-a-car-and-bike-mess
31. Garrick D. Car2go ceases San Diego operations [Internet]. The San Diego Union- Tribune; 2016 Dec 31 [Cited 2019 Jan 14]. Available from: https://www.sandiegouniontribune.com/news/politics/sd-me-car2go-leave- 20161230-story.html
32. The Local. Autolib: Why have the wheels come off the much-lauded Paris car- sharing scheme? [Internet]. The Local France; 2018 Jun 19 [Cited 2019 Jan 14]. Available from: https://www.thelocal.fr/20180619/whats-gone-wrong-with-the- much-lauded-paris-car-sharing-scheme
33. George SR, Zafar M. Electrifying the Ride-Sourcing Sector in California: Assessing the Opportunity [Internet]. California Public Utilities Commission, Policy & Planning Division; 2018 Apr [Cited 2019 Jan 16]. Available from: http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Divisions/Policy_and_Planning/PPD_Work/PPD_Work_Products_(20 14_forward)/Electrifying%20the%20Ride%20Sourcing%20Sector.pdf
34. Richardson DB. Electric vehicles and the electric grid: A review of modeling approaches, Impacts, and renewable energy integration. Renewable and Sustainable Energy Reviews. 2013 Mar 1;19:247-54.
35. Gómez JC, Morcos MM. Impact of EV battery chargers on the power quality of distribution systems. IEEE Transactions on Power Delivery. 2003 Jul;18(3):975-81

36. Singh B, Chandra A, Al-Haddad K. Power quality: problems and mitigation techniques. John Wiley & Sons; 2014 Dec 12.
37. Jin L, Searle S, Lutsey N. Evaluation of state-level US electric vehicle incentives. The International Council on Clean Transportation. 2014.
38. Slowik P., Pavlenko N., Lutsey N. Emerging policy approaches to electrify ride- hailing in the United States. The International Council on Clean Transportation. 2019 Jan 8.
39. Jin L, Slowik P. Literature review of electric vehicle consumer awareness and outreach activities. The International Council on Clean Transportation. 2017 Mar 21.
40. Krause RM, Carley SR, Lane BW, Graham JD. Perception and reality: Public knowledge of plug-in electric vehicles in 21 US cities. Energy Policy. 2013 Dec 1;63:433-40.
41. Arbib J, Seba T. Rethinking Transportation 2020-2030. RethinkX, May. 2017 May.
42. ICCT. Emerging policy approaches to electrify ride-hailing in the United States. The International Council on Clean Transportation. 2019 Jan.
43. Slowik P, Lutsey N. The continued transition to electric vehicles in US cities. The International Council on Clean Tranportation. 2018 Jul.
44. California Air Resources Board. The Zero Emission Vehicle (ZEV) Program. 2018 Oct 24. Available from: https://arb.ca.gov/msprog/zevprog/zevprog.htm
45. Senate Bill No. 1014. California Legislative Information. 2018 Sep 14.
46. Regional Air Quality Council. Clean Air Fleets. Available from: https://cleanairfleets.org/
47. He H, Jin L, Cui H, Zhou H. Assessment of Electric Car Promotion Policies in Chinese Cities. The International Council on Clean Transportation. 2018 Oct.
48. U.S. DOE. Alternative Fuels Data Center. Available from https://afdc.energy.gov/
49. EPRI. Environmental Assessment of a Full Electric Transportation Portfolio: Executive Summary. Available from: https://www.epri.com/#/pages/product/000000003002006881/?lang=en
50. Open Charge Map. Available from: https://openchargemap.org/site/
51. NREL. NREL's EVI-Pro Lite Tool Paves the Way for Future Electric Vehicle Infrastructure Planning. 2018 Mar 16 [Cited 2019 Jan 31]. Available from: https://www.nrel.gov/news/program/2018/nrels-evi-pro-lite-tool-paves-the-way-for- future-electric-vehicle-infrastructure-planning.html
52. Edelstein S. Renault Launches Electric Car-Sharing Service in Paris. 2018 Jul 4 [Cited 2019 Feb 5]. Available from: http://www.thedrive.com/tech/21945/renault- launches-electric-car-sharing-service-in-paris
53. Zipcar. Available from: https://www.zipcar.co.uk/electric
54. Maven Car Sharing. Available from: https://www.maven.com/us/en/index.html
55. Huang E. China's ride-hailing giant is getting into the electric-car business. Quartz. 2019 Jan 29 [Cited 2019 Feb 5]. Available from: https://qz.com/1536136/chinas- ride-hailing-giant-didi-is-getting-into-the-electric-car-business/
56. Siddiqui F. Lyft's 'Green Mode' will allow riders to opt for hybrid or electric vehicles. The Washington Post. 2019 Feb 6 [Cited 2019 Feb 6]. Available from: https://www.washingtonpost.com/transportation/2019/02/06/lyfts-green-mode-will- allow-riders-opt-hybrid-or-electric-vehicles/?utm_term=.c7bf8a5c1435
57. Lyft. Making Portland More Livable with Green Mode. Lyft Blog. 2019 Apr 25 [Cited 2019 Nov 15]. Available from: https://blog.lyft.com/posts/2019/portland- green-mode
58. Hawkins A. GM will rent the Chevy Bolt to Uber and Lyft drivers. The Verge. 2017 May 3 [Cited 2019 Feb 5]. Available from: https://www.theverge.com/2017/5/3/15521048/gm-maven-rideshare-gig-economy- uber-lyft
59. Uber UK. Uber's Clean Air Plan to help London go electric. 2018 Oct 23 [Cited 2019 Feb 5]. Available from: https://www.uber.com/en-GB/newsroom/uber-helps- london-go-electric/
60. Rodriguez M. Why Uber Is Paying Drivers More to Go Electric. Fortune. 2018 Jun 20 [Cited 2019 Feb 5]. Available from: http://fortune.com/2018/06/20/uber-drivers- switch-electric-cars/
61. Gerdes J. Tesla and Uber Weigh In on Policies to Boost EV Adoption. Greentech Media; 2018 Mar 7 [Cited 2019 Jan 31]. Available from: https://www.greentechmedia.com/articles/read/tesla-and-uber-weigh-in-on-policies- to-boost-ev-adoption#gs.gbtBmNGu
62. Li S, Mi CC. Wireless power transfer for electric vehicle applications. IEEE journal of emerging and selected topics in power electronics. 2015 Mar;3(1):4-17.
63. Spector J. Blockchain-Enabled Electric Car Charging Comes to California. Greentech Media. 2017 Aug 2 [Cited 2019

Feb 5]. Available from: https://www.greentechmedia.com/articles/read/blockchain-enabled-electric-car- charging-california#gs.gYDMMDTE

64. Kempton W, Tomić J. Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. Journal of power sources. 2005 Jun 1;144(1):280-94.
65. Kilbey B. Electric vehicle solid state battery technology likely a decade away: BMO. S&P Global. 2018 Nov 13. Available from: https://www.spglobal.com/platts/en/market-insights/latest-news/metals/111318- electric-vehicle-solid-state-battery-technology-likely-a-decade-away-bmo
66. Khan W, Ahmad A, Ahmad F, Saad Alam M. A comprehensive review of fast charging infrastructure for electric vehicles. Smart Science. 2018 Jul 3;6(3):256-70.