Challenges and Opportunities for Publicly Funded Electric Vehicle Carsharing

February 2022

A White Paper from the National Center for Sustainable Transportation

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16. Abstract Over the last six years, from 2016 through 2021, a wave of new federal, state, and local funding has supported carsharing services that use electric vehicles and install electric vehicle chargers to reduce greenhouse gas emissions (GHGs) and address climate change. In addition, many of these same funding programs allow support for the location of services in underserved communities with fare levels that enable community members to access these services. This study first explores the potential climate change benefits for carsharing services and the need for these services in underserved areas by reviewing the available published literature. Next, the study discusses the evolution of carsharing in the U.S., including non-profit, for-profit, and recent government-funded carsharing, drawing on published reports, newspaper articles, and expert interviews. Finally, the authors draw conclusions of relevance for future government-funded carsharing programs.		
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Glossary

Acronym	Definition
API	application programming interface
BEV	battery electric vehicle
CARB	California Air Resources Board
CCI	Climate Change Investment
CMAQ	Congestion Mitigation and Air Quality
DOE	Department of Energy
EJN	Environmental Justice Neighborhoods
EVSE	electric vehicle supply equipment
GHG	greenhouse gas
HEV	hybrid electric vehicle
ICEV	internal combustion engine vehicle
NYC	New York City
PHEV	plug-in hybrid electric vehicle
VMT	vehicle miles traveled

Challenges and Opportunities for Publicly Funded Electric Vehicle Carsharing

EXECUTIVE SUMMARY

Over the last six years, from 2016 through 2021, a wave of new federal, state, and local funding has supported carsharing services that use electric vehicles and install electric vehicle chargers to reduce greenhouse gas emissions (GHGs) and address climate change. These programs range from two-vehicle to 300-vehicle programs, with a broad range of funding mechanisms and levels, often ranging between two-year and five-year initial service periods. In addition, most of these funding programs allow support for the location of services in underserved communities with fare levels that enable community members to access these services. The largest funder of these programs is the California Air Resources Board, which has invested or reserved over $70 million in funding for these programs since 2015.

Moreover, funding for electric carsharing is growing. Carsharing is eligible for $13.2 billion in congestion relief and air quality improvement funds from President Biden's Infrastructure Investment and Jobs Act. The latest version of the Build Back Better Bill supports $1 billion for an electric vehicle infrastructure in underserved communities. New York State recently dedicated $200 million electric vehicle infrastructure and $85 million for electric carsharing and ridesharing to be invested in marginalized communities. California is poised to spend an additional $18 million over this next year in similar programs.

The goal of this study is to help inform the design and improve the value of investments in future electric carsharing programs: (1) by reviewing the academic literature that evaluates the travel, GHG, and equity effects of implemented carsharing programs in the U.S.; and (2) by analyzing the evolution of carsharing in the U.S., including non-profit, for-profit, and recent government-funded carsharing. Thus, the ultimate goal of this study is to allow researchers, policy makers, urban planners, and others to glean insights and identify unanswered questions about government electric carsharing investments.

Lesson Learned #1: Carsharing, especially with electric vehicles, is likely to reduce GHG emissions.

Our review of academic literature that evaluates U.S. carsharing programs from 2004 to 2021 shows reductions in vehicle miles traveled and associated GHG emissions, especially for round-trip carsharing, based on self-reported pre-and post-carsharing surveys. The evaluations also suggest that carsharing members often decreased vehicle ownership and forwent the purchase of an additional vehicle. Furthermore, the studies indicate that round-trip carsharing does not reduce transit use. In some cases, it increases, often serving to complement trip types and destinations that are more challenging to serve with fixed-route transit. The use of electric carsharing would tend to further increase GHG reduction benefits compared to conventional vehicle carsharing.

Lesson Learned #2: Private carsharing services are likely to limit service to urban areas with high demand where residents can pay the market rate fares.

Our review of the evolution of carsharing services in the U.S, not surprisingly, shows that commercial carsharing services locate their services where they can make a reasonable profit for their efforts. Such locations have high usage rates by members who can afford profit-making fares. Private sector companies, whose sole business was carsharing (such as Mint and the original Zipcar), were acquired by rental car companies. In the U.S. today, non-peer-to-peer carsharing is primarily operated by rental car companies, and carsharing is part of a diversified business model.

Our literature review shows that private sector carsharing tends to be in major metropolitan urban areas with high-quality transit and in neighborhoods where residents are affluent (median to high incomes), highly educated, young, and white. In addition, reviews of the publicly available location data since the Enterprise and Avis acquisitions indicate significant service cutbacks occurred in less profitable low-income communities. In contrast, service consolidated in profitable markets, typically in dense high-income areas with high-quality transit and on or near college campuses. Moreover, published studies by Kim (2015), Tyndall (2017), Mitra (2021), and Kodransky and Lewenstein (2014) confirm that the geographic distribution of services and service costs have been key barriers to accessing carsharing among marginalized populations.

Lesson Learned #3: In the short term, most private sector carsharing will likely continue to use conventional or hybrid vehicles.

There is no example of a commercially successful electric carsharing program to date because of the lack of developed and consistently reliable electric vehicles and infrastructure. Three automakers—Daimler, GM, and BMW—launched major carsharing initiatives in the U.S., including some electric vehicle fleets, and, in 2020, each shut down operations nationwide. Where these operators piloted electric carsharing, such as the Car2go (Daimler) program in San Diego, these electric vehicle-dependent markets were some of the first to close due, in part, to challenges with electric vehicles and infrastructure. Hyundai, the most recent automaker trying to make a go of carsharing services in Los Angeles, announced in fall 2021 that it would end services by the end of the year before even bringing electric vehicles into their fleet mix. The exception is GIG carsharing, funded by AAA, which uses electric vehicles in Sacramento. However, a grant subsidized the electric vehicles and infrastructure. Until electric vehicles become competitive with hybrid sedans and charging infrastructure becomes more widespread, subsidies for electric vehicles and charging infrastructure for carsharing services are critical to soften operational risks. As such, cities will be challenged to attract these larger private sector partners to small-scale pilots in disadvantaged communities that lack this infrastructure and are often not proximal to their preferred market. In other words, the combination of EVs with the prioritization of low-income communities presents a barrier to entry for a retrenched private sector in this industry.

Lesson Learned #4: Non-profit carsharing continues to be feasible in the U.S. and may be one approach to expanding service beyond the service boundaries of private sector carsharing.

This study also suggests that sustainable local non-profit carsharing programs that address environmental and social goals in their community are possible inside and outside of major urban areas. For many years, non-profit carsharing operated at a large-scale in major metropolitan areas (e.g., San Francisco Bay Area, Chicago, and Philadelphia). However, the emergence of ride-hailing companies in 2010 and the dominance of for-profit carsharing services run by rental car companies from 2010 to 2012 preceded the decline in non-profit carsharing. In addition, rental companies acquired many non-profit carsharing services. Nevertheless, four long-established non-profit carsharing programs continue to provide services in large and small urban areas and are largely self-sustaining. Two of these programs, Ithaca Carshare and Carshare Vermont, were interviewed as part of this study and reported that 1% to 20% of non-profit carsharing revenue typically comes from private or government contracts. In addition, service can expand with an infusion of public funds (e.g., in Colorado and the Twin Cities).

Lesson Learned #5: In recent years, public or community-controlled electric vehicle carsharing projects show progress towards effectively increasing equity of access in marginalized populations, as measured by these programs' ability to sustain operations.

Researchers reviewed 12 projects supported by the new wave of carsharing programs, which included the use of electric vehicles and/or low-cost services in underserved communities. We categorized these programs and described their progress.

Public or Community-Controlled Programs: The first category of projects includes four public programs initiated and supported by cities, counties, or metropolitan regions with the explicit intention of providing an enduring public service. Most of these programs range in scale from large (Los Angeles at 100 current and 300 planned electric vehicles), to moderate (San Joaquin at 27 current and 95 planned electric vehicles and Twin Cities at 150 planned electric vehicles), to small (Sacramento at 22 electric vehicles). All four programs have recently launched and/or are expanding operations. The Los Angeles and Sacramento programs have relationships with vendors that own the electric vehicles and operate the carsharing service. Miocar and Hourcar are non-profits that own electric vehicles and operate their carsharing service in-house. All programs address issues of affordability with below-market-rate pricing. Carsharing services are almost exclusively located in underserved communities and often with affordable house developments. The programs are funded mainly through public investments. The California Air Resources Board (CARB) and the U.S. Department of Energy (DOE) are the two largest investors in these models. As an exception, the BlueLA program in Los Angeles secured significant private funding commitments in both the program's first and second phases.

Public-Private Demonstrations: This includes pilots/demonstrations with public funding. These programs receive funds from a public agency to test specific goals and typically originate from a pre-existing public-private partnership formed before the investment of public funding. Private carsharing companies manage the program's operations with varying degrees of public oversight. As a result, these public-private investments are on a shorter term, hence limited to pilot/demonstrations, as compared to the public or community-controlled projects described above. Three of the four projects in this category have ended. The Sacramento Envoy project, with GHGs and equity goals, is still ongoing but reduced its battery electric vehicle (BEV) fleet by two-thirds (from 142 Electric vehicles to 48 electric vehicles). The scale of two of these projects (San Diego Car2GO and BlueIndy) was significant (300 electric vehicles and 282 electric vehicles, respectively). GHG reductions were the goal of both programs. With GHG and transit accessibility goals, the Chattanooga program included 20 electric vehicles and operated for three years.

Private Ventures and Non-profit Demonstrations: The third category includes privately led public-private partnerships and non-profit demonstrations with a clear end date. Privately administered and sponsored, these projects may receive grant money and/or public space. However, outside of their grants and public space agreements, these programs are independent of public oversight. Two of the four projects included in this category have ceased operations (Portland's Hacienda and Los Angeles' Hyundai Mocean). The other two are currently operational (Sacramento's GIG and CRuSe in Hood River, Oregon). The Oregon programs are small (3-5) pilots to test GHG and equity goals. Mocean included 100 electric vehicles and focused on increased accessibility. GIG operates 260 electric vehicles in a 13 square mile of central Sacramento. Its objectives are GHG reductions and improved accessibility.

Lesson Learned #6: There is a need for more evaluation of costs, benefits, and designs that incorporate lessons learned from evaluations.

Electric vehicle carsharing is a promising policy and infrastructure option to reduce vehicle travel and GHGs and improve equity of access. These services act as incentives for changing behavior, which is necessary where few alternatives to personal vehicles are available. Subsidized electric carsharing programs may provide an affordable option to high-quality transit that is costly to provide in rural and suburban areas. Pricing policies are very effective at inducing behavioral change. Still, they are likely to face extreme pushback from constituents who must travel long distances to access affordable housing and employment in suburban and rural areas. Electric carsharing may increase exposure to electric vehicles in rural areas, translating to acceptance and increasing the likelihood of electric vehicle purchases, at least among those who can afford such purchases.

On the other hand, researchers know little about what these new wave projects will cost at scale and their actual benefits. It is critical to conduct peer-reviewed evaluations of these programs to verify and quantify the magnitude of benefits. Many of these programs use different business models and locate in different geographic contexts. Lessons learned from these programs should be documented over time as projects grow, evolve, and mature.

Funding programs should reserve at least ten percent of project costs for research evaluation at this emergent stage. Evaluations need to move beyond usage data and integrate surveys (with reasonable response rates) and focus groups. This data is necessary to understand and document changes in travel behavior, GHG emissions, and access to opportunities for marginalized populations. Currently, ongoing funding mechanisms for these electric carsharing programs are uncertain. Peer-reviewed evaluations are necessary to justify the development of a funding mechanism to support these programs. Notably, CARB has increased its funding for evaluation, but more support is needed.

1. Introduction

Over the last six years, from 2016 through 2021, new federal, state, and local funding has supported carsharing services that use electric vehicles and install electric vehicle chargers to reduce greenhouse gas emissions (GHGs) and address climate change. Since 2019, these programs have accelerated considerably. In addition, many of these same funding programs focus on service to marginalized communities and low-income users in particular. The implemented programs vary widely in terms of: fleet sizes, ranging from 2 to 300 vehicles; and funding mechanisms and levels, and during of initial service periods from 2 to 5 years. The largest funder of these programs is the California Air Resources Board, which has invested or reserved over $70 million in funding for these programs since 2015.

Funding for electric carsharing is growing. Carsharing is eligible for $13.2 billion in congestion relief and air quality improvement funds from President Biden's Infrastructure Investment and Jobs Act. The latest version of the Build Back Better Bill supports $1 billion for an electric vehicle infrastructure in underserved communities. New York State recently dedicated $200 million electric vehicle infrastructure and $85 million for electric carsharing and ridesharing in marginalized communities. California is poised to spend an additional $18 million over this next year in similar programs.

The goal of this study is to help inform the design and improve the value of investments in future electric carsharing programs: (1) by reviewing the academic literature that evaluates the travel, GHG, and equity effects of implemented carsharing programs U.S. and (2) by analyzing the evolution of carsharing in the U.S., including non-profit, for-profit, and recent government-funded carsharing, to glean insights and identify unanswered questions about government electric carsharing investments.

2. Literature Review

This section reviews the literature that evaluates carsharing in the U.S. and Canada . First, we explore changes in passenger travel, including transit use, vehicle miles travel (VMT), and greenhouse gas (GHG) emissions from round-trip and one-way carsharing services. Next, we explore issues related to equity of access to carsharing services and the degree to which carsharing has increased access to opportunities in underserved communities. The objective of this literature review is to understand the available peer-reviewed evidence for changes in travel behavior, GHGs, and equity of access for the new wave of electric carsharing programs.

2.1 Travel and Emissions

Table 1, at the end of this section, summarizes the research described in the text here.

One of the first evaluations of a large-scale carsharing service is the Cervero and Tsai (2004) study of the San Francisco carsharing service, City CarShare. The non-profit corporation operated a round-trip carsharing service with conventional (i.e., internal combustion engine) vehicles. Over two years, they implemented a series of surveys that collected information about individuals, households, car ownership, and travel demand. They collected detailed travel diary information from City Carshare members and non-members, who served as a statistical control group. Survey response rates were 26% (462) for members and 34% (54) for non-members. Surveys asking members about their service use received responses from 351 members who tended to be frequent City CarShare users. See Table 1 for a summary of travel and emissions results for carsharing studies.

Cervero and Tsai (2004) found that early adopters of City CarShare were young (43.2% between the ages of 25 and 34), majority female (57.1%), and white (81.2%). Most members came from zero-car households (56.7%) and one-car households (33.7%). During the first two years of operation, more City Carshare members reported reducing their car ownership compared to nonmembers (29.1% versus 8%) by a statistically significant amount. Additionally, a larger share of members reported foregoing the purchase of an additional vehicle compared to non-members (67.5% versus 39.2%). While the results of foregone vehicle purchases were interesting, they were not statistically significant at the 0.05 level. Average VMT fell slightly for members and increased for non-members. After adjusting VMT for confounding factors such as mode and engine size, researchers found an even larger decline in VMT among members; however, this result was not statistically significant. Cervero and Tsai suggest that reduced car ownership, selective vehicle use, and higher than average vehicle occupancy rates accounted for the reductions in VMT among City CarShare members. Additionally, the researchers estimated that average carbon dioxide (CO_2) emissions during the 2-year period fell by 0.75 pounds for members and increased by 0.25 pounds for nonmembers. Based on a best-fitting regression model, which controlled for factors such as travel day and respondents' socio-economic status, the researchers found statistically significant results that City CarShare membership typically lowered members' daily gasoline consumption by nearly 0.25 gallons.

Another study describes the Philadelphia-based carsharing service's evaluation, PhillyCarShare (Lane 2005). This non-profit operated a round-trip program with a combination of conventional and hybrid electric vehicles (HEVs). Lane administered a survey online and by mail to 502 members and received 262 responses, constituting a response rate of 52%. To estimate VMT impacts, he used vehicle usage data from PhillyCarShare, and a personal vehicle travel self-assessment completed by members on their PhillyCarShare application. In addition, PhillyCarShare located vehicles in Philadelphia's most densely populated areas, and most members lived or worked nearby.

Similar to the second-year findings of Cervero and Tsai (2004), Lane's (2005) findings showed that early adopters of PhillyCarShare were young (55% between the ages of 25 and 39), white (89%), and owned zero vehicles (61%). Additionally, members were highly educated (99.6% attended college), lived alone or with a significant other (93%), and frequently used transit (91%). During PhillyCarShare's first year of operation, 24.5% of members reported reducing owned vehicles, and 29.1% avoided purchasing an additional vehicle. Members who reduced car ownership reported driving less and increasing their use of other forms of transportation, such as walking, biking, transit, and taxis. The majority of members who did not previously own a car reported no significant change in their transit use after starting PhillyCarShare. Members who did not have access to a vehicle before joining PhillyCarShare increased their VMT at most by an average of 29.9 miles each month. However, Lane estimated that members who gave up a car after using PhillyCarShare saw a monthly VMT decrease.

Martin and Shaheen (2011) evaluated the impact of round-trip carsharing services in North America on GHG emissions. The study included AutoShare in Toronto (CAN); City CarShare in San Francisco (CA); CityWheels in Cleveland (OH); Community Car Share in Bellingham (WA); CommunAuto in Montreal (CAN); Community Car in Madison (WI); Co-operative Auto Network/The Company Car in Vancouver (CAN); IGo in Chicago (IL); PhillyCarShare in Philadelphia (PA) and Wilmington (DE); VrtuCar in Ottawa (CAN); and Zipcar (U.S. and CAN). The authors surveyed participants about their travel behavior before and after starting carsharing. Most participating carsharing services sent out survey invitations to their entire member base. However, due to Zipcar's services' size and geographic spread, Zipcar only allowed 30,000 survey invitations. Therefore, the researchers estimated that 100,000 carsharing members received the survey. Participants completed 9,635 surveys with a 10% response rate. The final analysis included 6,281 responses. The survey included questions on automotive usage, type of household vehicle(s), and demographic information.

Martin and Shaheen (2011) found that nearly half of respondents reported a 2007 household income higher than $60,000. Additionally, most respondents held at least a bachelor's degree (80%), and a large portion had completed an advanced graduate degree (40%). The average respondent household size was 1.9 persons, which was smaller than the national average at the time of the study. Most respondents identified as female (57%) compared to male (43%). Respondents primarily belonged to zero-vehicle households (62%) and one-vehicle households (31%).

Before using the carshare services, Martin and Shaheen (2011) reported, respondents collectively owned 2,968 vehicles, and after carsharing, respondents owned 1,507, a decrease of nearly 50%. Out of the 6,281 households in the sample, households shed 1,461 vehicles, constituting a statistically significant reduction in the average number of vehicles per household. They calculated GHG impacts from the change in annual overall automotive use (before and after using carsharing services). More carsharing members increased emissions than decreased emissions after joining a carsharing service; however, the impact for those who decreased emissions was more significant. Overall, the sample saw a reduction in GHG emissions. The average change in emissions across all households included in the study was −0.58 ton GHG per household for the observed impact and −0.84 ton GHG per household for the full impact, which included the unobserved impact, such as avoided vehicle purchases. The results of both the observed impact and the full impact were statistically significant. Respondents who decreased their emissions exhibited changes on a larger magnitude with greater variance. Most respondents reported utilizing a carsharing vehicle for short travel distances.

Martin and Shaheen (2016) analyzed Car2go's impact on vehicle ownership, mode shift, vehicle miles traveled, and GHGs in five North American Cities. The Car2go cities included in the study were Calgary, San Diego, Seattle, Vancouver, and Washington, D.C. All cities operated a conventional vehicle fleet except for San Diego, which included all battery electric vehicles (BEVs). In addition, Car2go operated a one-way free-floating carsharing fleet, in which drivers do not have to return the vehicle to a specific location. The authors used a combination of survey and vehicle usage data. Survey questions assessed Car2go's impact on private vehicle ownership and forgone vehicle purchases and mode shifts. Additionally, researchers used vehicle activity data to determine the total miles driven by each city's Car2go fleet and frequency of use. They distributed an online survey to Car2go members in the five cities of interest between 2014 and 2015, and 9,497 members completed the survey. They used a total of 9,497 samples to assess mode shift; however, a smaller sample (6,167 due to data cleaning) to calculate vehicle usage, VMT, and GHG impacts.

Martin and Shaheen (2016) found that most respondents had not changed their travel mode after becoming a Car2go member. This result was consistent across almost every city and travel mode. However, in each city, respondents both increased and decreased public transit use. More respondents reported a decrease in their public transit use, rather than an increase, due to the presence of Car2go, except for Seattle, where more respondents reported an increase in their public transit use. One-way carsharing compared to two-way carsharing may be more strongly associated with a decrease in transit use because one-way but not two-way carsharing may cost less in time and money than a transit trip does. In two-way car sharing, the additional costs and potentially greater inconvenience arise from having to pay for the car while it sits at the destination and having to return it to the origin point.

Overall, the researchers found that Car2go members reduced VMT, particularly when considering foregone vehicle purchases. To measure the change in VMT, they calculated the net difference between the miles generated by Car2go vehicles and the miles not traveled by sold vehicles and foregone purchases. Next, they calculated the associated GHG emission impacts by estimating the amount of fuel by type consumed by the sold and foregone vehicles. Researchers estimated VMT decreased by 6% to 16% per household, with an associated decrease in GHG emissions by 4% to 18% per household for the five cities. It is important to note that Martin and Shaheen (2016) did not include any analysis to determine the statistical significance of the included results.

Randall (2011) conducted a two-year study of the Buffalo CarShare service. Member surveys asked retrospective questions about the impacts of the service on members' behavior. The response rate was 33% (N=134). Member respondents indicated that they shed vehicles (4%), delayed purchase of a vehicle (27%), and decided to purchase a vehicle (20%). In addition, survey responses indicated that members increased their transit use after joining the service and used transit to access the vehicles. Overall, the analysis indicated a reduction in VMT and vehicle fuel due to participation in the carsharing program.

Clewlow (2016) used the California Household Travel Survey (2010-2012) data to analyze travel behavior among carsharing members in the San Francisco Bay Area. From a total statewide sample of 63,082 responses (4.9% response rate) and a subsample of Bay Area residents, she selected households in census tracts with access to carsharing (79.3% of the Bay Area subsample). This final sample included 1,280 household responses and 2,719 individual responses. Carsharing members accounted for 19.8% of household responses and 13.9% of individual responses, while the remaining responses of non-members served as the control group. Clewlow defined a "carsharing household" as a household with at least one carsharing member. The control group included households and individuals in the subsample who did not carshare and lived in a census tract with access to carsharing.

Consistent with the findings of Cervero and Tsai (2004) and Lane (2005), Clewlow's findings showed that a higher percentage of carsharing members had at least a bachelor's degree (83.5%) compared to non-carsharing members (69.5%). Additionally, a larger percentage of carsharing households had an annual income of $100,000 or higher compared (59%) than non-member households (37.2%). The study found that carsharing members owned significantly fewer vehicles than non-members in urban areas (0.58 cars versus 0.96 cars). In the suburban areas of the study, the study did not show a statistical difference between the vehicle ownership of members and non-members. Moreover, based on the Bay Area sample, nearly one-third of carsharing members came from zero-vehicle households (30%), while the non-carsharing control group had significantly fewer zero-car households (8%). Among all car-owning households in the subsample, Clewlow found a greater share of owned alternative vehicles, including HEVs, plug-in hybrid electric (PHEVs), and BEVs in the carsharing group. The data showed that carsharing members reported lower daily average VMT than non-members. However, this result was only significant for households in the lower-density areas of the study. A slightly higher percentage of carsharing members used public transit compared to non-members.

Shaheen, Martin, and Totte (2020) studied how exposure to BEVs and PHEVs through a U.S. carsharing fleet affected sentiment toward electric-powered vehicles. They drew a sample of carsharing members from four carsharing operators and across seven cities in the U.S.: Car2go located in San Diego, Portland, and Austin; DriveNow/ReachNow in San Francisco; Zipcar in Boston and New York City; and eGo Carshare in Boulder. Car2go and DriveNow/ReachNow operated as one-way carsharing, while Zipcar and eGo CarShare were round-trip carsharing services. In addition, the Car2go fleet in San Diego and the DriveNow/ReachNow fleet in San Francisco included only BEVs, while the other fleets contained a mix of BEVs and conventional vehicles.

Shaheen, Martin, and Totte (2020) study included a sample of carsharing members divided into experimental and control groups. The experimental group included carsharing members exposed to a carsharing BEV. The control group included carsharing users not exposed to a BEV through carsharing. There were two sources of data: vehicle activity data provided by the carsharing operator and surveys—one experimental survey and one control survey). The experimental survey received 1,920 responses (74% completion rate), and the control survey received 1,742 responses (77% completion rate). The sample population was well educated (83% of experimental and 85% of the control group were working towards or had completed a bachelor's degree), majority white (77%), and majority middle income or higher.

The majority of the experimental group (78%) confirmed exposure to BEVs through carsharing, one-fourth (25%) reported exposure to PHEVs through carsharing, and another on-fourth reported that carsharing was their only exposure to electric vehicles (Shaheen et al. 2020). There were low rates of electric vehicle ownership in both the experimental group (4% owned BEVs and 2% owned PHEV) and the control group (2% owned BEVs and 2% owned PHEVs). However, the experimental and control group comparison showed that a more significant percentage of respondents exposed to PHEVs/BEVs expected their next vehicle purchase to be an electric vehicle (17%) relative to the control group (12%). When asked about purchasing an electric vehicle before using carsharing, these proportions differed: 5% of the experimental group versus 7% of the control group reported interest in purchasing an electric vehicle before carsharing. Moreover, carsharing members with BEV and PHEV exposure were more likely to recommend these vehicles to others. Eighty percent (80%) of the experimental group versus 59% of the control group agreed or strongly agreed to recommend that others try driving electric vehicles. Fifty-six percent (56%) of the experimental group versus 47% of the control group would recommend that others purchase an electric vehicle. A small percentage of respondents would not recommend electric vehicles, and this response was similar across the experimental and control groups. In addition, researchers found a positive correlation between electric vehicle use and positive sentiments toward electric vehicles in the experimental group. Members who used electric vehicles through carsharing more than once a month had expressed more willingness to use and purchase electric vehicles than members who used electric vehicles through carsharing once a month or less.

Martin et al. (2021) studied the effects of a New York City pilot program that increased dedicated on-and off-street parking spaces for ZipCar and Enterprise CarShare vehicles in areas with traditionally low carsharing rates. At the time, both ZipCar and Enterprise CarShare operated round-trip services. The pilot initially included the one-way carsharing operator, ReachNow, but operations in the area ended before the pilot began. As a result, ReachNow member data were included in the analysis of the first retrospective survey only (see discussion below), administered before the program's start—the pilot program allocated up to 300 on-street parking spaces and 300 off-street parking spaces to carsharing vehicles. Upon the pilot's launch, the New York City Department of Transportation distributed 230 on-street parking spaces and 55 off-street parking spaces to ZipCar and Enterprise CarShare across 14 geographically and economically diverse neighborhoods in Manhattan, Brooklyn, Queens, and the Bronx.

Study data included responses from three surveys administered to different user populations and vehicle activity provided by ZipCar and Enterprise CarShare. All three surveys asked questions about user households, vehicle ownership, travel patterns, and demographics. The first survey, which included retrospective questions about members' use of the carsharing service, received 2,700 responses from New York City residents who were carsharing members before the pilot program's launch (Martin et al., 2021). The retrospective survey gathered information on travel behavior trends and car ownership among carsharing members. Respondents to the retrospective survey were majority male (59.9%) and white (57.3%), high income (25% with income $200,000 or more), and highly educated (44.7% with bachelor's and 44.7% with post-graduate degree). The second survey, the "before survey," received 1,051 responses and was administered to new members of ZipCar and Enterprise CarShare after the pilot program's start. The third survey, the "after survey," received 841 responses and concentrated on behavioral changes due to the pilot program.

The results indicated a modest reduction in personal vehicle ownership, VMT, and GHG emissions. A small percentage of respondents reported avoiding purchasing an additional car (7%), and an even smaller percentage reported getting rid of an owned vehicle due to carsharing (0.61%). The researchers estimated a 7% reduction in VMT and a 6% reduction in GHGs across the membership base. Carsharing in New York City appeared to substitute for other forms of conventional vehicle travel, such as car rentals and personal vehicle use, and it more frequently led to a gain in mobility rather than substituting for the primary mode of transportation used. However, some members reported reducing their transit use after carsharing. Members who reduced their use of public transit said they did so because transit routes did not serve the area well enough (30%), carsharing was faster (26%), and carsharing allowed better transport of packages and groceries (15%). Additionally, Martin et al. (2021) note no significant correlation between carsharing use and the proximity of the added parking locations to respondents' homes or work.

Rodier, Harold, and Zhang (2021) explored early results from the BEV carsharing pilot program (Miocar) in underserved rural communities in the San Joaquin Valley. Miocar operates a round-trip station-based model with 24 BEVs and 3 PHEVs. Affordable housing complexes host carsharing hubs across eight sites. Researchers collected data through member applications, initial member surveys, post-reservation surveys, and vehicle telematics software equipped by

Miocar. Early findings, which integrated survey results (50% response rate) with user data, showed 15% of electric VMT by Miocar replaced conventional VMT. In addition, the service did not replace transit trips; however, members used transit to access Miocar hubs (Rodier et al., 2021).

Table 1. Summary of Studies Evaluating the Effects of Carsharing on VMT and Greenhouse Gas Emissions

Source	Study Location	Sample	Methods	Carsharing Type	Vehicle Type	Vehicle Ownership	Transit Use	Vehicle Emissions
Cervero and Tsai (2004)	San Francisco	n=462 members, n=54 nonmembers (RR 25.5% and 34%)	Before and after surveys with control group.	Round-trip	Conventional	29.1% members vs. 8% non-members shed cars, 67.5% of members vs. 39.2% of non-members forego purchase	NA	Member VMT decreases vs non-member increases; CO_2 falls by 0.75 lb for members and 0.25 lb for non-members
Lane (2005)	Philadelphia	n=262 (52% RR)	Member survey and usage data	Round-trip	HEV and conventional	Average of 23 private vehicles replaced per carshare vehicle due to shed vehicle and foregone purchases	Increase in transit use for shed vehicle households, but no change for zero-car households	VMT increased by 29.9 mi for members gaining car access; VMT decreased for members who shed vehicles
Martin and Shaheen (2011)	North America	n=6,281 (10% RR)	Retrospective before and after survey	Round-trip	Mixed	50% decrease in car ownership	NA	−0.58 t GHG to −0.84 per household
Randall (2011)	Buffalo	n=134 (33% RR)	Retrospective member survey	Round-trip	Conventional	4% shed car; 27% delayed purchase; 20% decided not to purchase	Used transit more and used transit to access hub	Reduced gas and VMT

Source	Study Location	Sample	Methods	Carsharing Type	Vehicle Type	Vehicle Ownership	Transit Use	Vehicle Emissions
Martin and Shaheen (2016)	Calgary, San Diego, Seattle, Vancouver, and Washington, D.C.	n=9,497 mode shift; n=6,167 vehicle travel and GHGs	Retrospective before and after survey, and vehicle usage data	One-way free floating	Conventional and BEV in San Diego	2%-5% shed vehicle, 7%-10% forgo purchase	Most reported no significant change	Average household VMT reduced by 6% to 16%; GHGs reduced by 4% to 18%
Clewlow (2016)	San Francisco Bay Area	n=1280 households; n=2719 individuals	2010-2012 California Household Travel Survey	Mixed	NA	1.10 average household vehicles for members vs. 1.37 for non-members	Members made 14.5% of trips by transit vs. 10.3% of non-members	Carsharing members had a daily average VMT less than non-members
Shaheen, Martin, & Totte (2020)	San Diego, Portland, Austin, San Francisco Bay Area, Boston, New York City, Boulder	n=1,920 experimental (74% completion rate), n=1,742 control (77% completion rate)	Survey to experimental group of EV carsharers and control group of non-EV carsharers	One-way	Mixed	PHEVs/BEVs exposure increased interest EV purchases	NA	NA
Rodier, Harold, and Zhang (2021)	Central Valley, California	n=94 members, n=650 post-reservation (50% RR)	Initial member survey, post-reservation survey, user data	Round-trip	BEV	Average of 1.7 household vehicles	12% traveled to Miocar by public transit and no substitution of carsharing for transit.	Avoided conventional vehicles travel (17% trips and 15% miles); increased electric vehicle travel (63% trips and 75% miles)

2.1.1 Summary

It is essential to note that studies reviewed face challenges related to low response rates, limiting our confidence that responses truly represent the sampled population, and rely on stated retrospective surveys rather than observed data. Given this, the body of available evidence to date suggests that carsharing members appear to reduce VMT and associated GHG emissions, especially for round-trip carsharing, based on self-reported pre-and post-carsharing surveys and when compared to a non-carsharing control group (Martin and Shaheen 2016; Cervero and Tsai 2004; Martin et al. 2021). Martin and Shaheen (2011) found that more respondents increased their emissions than decreased. Still, the increase in emissions was very small, while respondents reducing their emissions did so to a larger degree with greater variance. Alternatively, Lane (2005) found that members who gained access to an additional vehicle due to carsharing increased their VMT, but members who gave up a car after using carshare saw a monthly VMT decrease. In Clewlow's study (2016), carsharing members reported an average daily VMT lower than VMT reported by non-members; however, this result was only significant for households in low-density areas of the study.

The research reviewed here also suggest that carsharing members often decreased vehicle ownership and forwent purchase an additional vehicle (Martin and Shaheen 2011; Martin and Shaheen 2016; Cervero and Tsai 2004; Lane 2005). Compared to a control group of non-carsharing households, members reported higher vehicle reduction and suppression rates than non-members (Cervero and Tsai, 2004). Clewlow (2016) observed personal vehicle reduction for three types of carsharing (station-based, one-way, and free-floating), that carsharing members owned significantly fewer vehicles than non-carsharing members, and lower levels of vehicle ownership among households in urban areas. Additionally, high percentages of carshare participants reported that they belonged to zero-car households (Clewlow 2016; Cervero and Tsai 2004; Lane 2005; Martin and Shaheen 2011).

The impact of carsharing on transit use varied across studies. Martin and Shaheen (2016) observed carsharing members increasing and decreasing public transit use after starting a carshare. More members reported a decrease in public transit use rather than an increase. However, most respondents reported that carsharing had not substantively changed their usual mode of travel. Alternatively, Lane (2015) observed a difference in transit use between station-based carsharing members who reduced vehicle ownership and carsharing members who did not previously own a car before carsharing. In contrast, members who did not own a car reported that carsharing did not change transit use. When comparing carsharing and non-carsharing samples, Clewlow (2016) found that a slightly higher percentage of carsharing members used public transit than non-members. In Martin et al. (2021), common reasons given by members who reduced their transit use after carsharing included transit routes did not serve the desired destination well enough, carsharing was faster, and carsharing allowed better transport of packages and groceries. However, overall transit use did not change.

2.2 Equity

This section reviews the literature on the equity impacts of carsharing. We begin by comparing the socio-demographic attributes of populations that have traditionally used carsharing from the literature reviewed above. Next, we review the literature that evaluates equity of carsharing service coverage by for-profit carsharing services. Finally, we examine the effects of carsharing programs with specific equity objectives. The review describes the available evidence about whether for-profit carsharing services a diverse range of populations and the impacts of programs that focus on equity of access for marginalized communities.

2.2.1 Socio-Demographic Attributes

Socio-demographic attributes discussed include age, race/ethnicity, education, household size, and income. In the papers reviewed, carsharing members are predominately young, white, college-educated, and middle income. Table 2 summarizes the socio-demographic attributes of members in traditional carsharing programs.

2.2.1.1 Age

Early adopters of carsharing tended to be young, mainly in their mid-twenties to mid- to late-thirties. Cervero and Tsai (2004) found that 43.2% of City Carshare members were between the ages of 25 and 34 compared to 27.8% of San Francisco’s general population, while the median age was 36 for both the City Carshare sample and general San Francisco population. Similarly, early adopters of PhillyCarShare were 38.5 years, and more than half of the members were between 25 and 39 (Lane 2005). Martin and Shaheen (2011) found that 43.1% of members were between 25 and 35 and had a mean age of 36.6 years. Additionally, the proportion of carsharing respondents decreased as the age bracket increased, and over one-third of respondents were over the age of 40. Martin et al. (2021) had similar results across the retrospective, before, and after surveys. The majority of surveyed carsharing members in Martin et al. (2021) were between the ages of 25-34 and 35-44, which was an overrepresentation compared to estimates for the general population. The member sample of 45 and 54 was similar to the general population, but older adults skewed lower. Clewlow (2016) found roughly similar proportions of respondents between the ages of 31 and 40 (24.6%), 41 and 50 (25.7%), and 51 and 60 (22%). Likewise, for these age groups, the percentage of carsharing members was larger than that of the control group of non-members, but the percentage over the age of 60 was smaller in the carsharing population than in the control group.

2.2.1.2 Race/Ethnicity

When considering the racial demographics of early adopters of carsharing, Cervero and Tsai (2004) found that the vast majority of carsharing respondents were white (81.2%) compared to San Francisco residents (49.6%). Lane (2005) observed a slightly higher percentage of white carsharing members (89%). The recent literature provides more complete categories of race and ethnicity. Based on the entire sample of carsharing members, Shaheen, Martin, and Totte (2020) found that the proportion of white carsharing members was higher than the general population in the United States (77% of carsharing members vs. 62% of the U.S. population).

Additionally, Shaheen, Martin, and Totte (2020) found that the proportion of Asian carsharing members was slightly higher than the general population and Hispanic/Latino, African American, American Indian/Alaskan, and Native populations were underrepresented. Martin et al. (2021) found that the percentage of white respondents was higher than the general population estimate. Furthermore, Asian carsharing members were slightly underrepresented, while the proportion of Black or African American and Hispanic or Latino were significantly lower than the population estimates. Martin et al. (2021) note that the proportion of Black or African American, Asian, and Hispanic or Latino respondents increased slightly in the before and after surveys relative to the retrospective survey.

2.2.1.3 Education

The majority of carsharing members had received at least a bachelor's degree. In Lane (2005), almost the entire sample of PhillyCarShare members reported attending college (99.6%). Additionally, he notes that education levels seemed to be the strongest predictor of early carsharing adopters. Martin and Shaheen (2011) found that the majority of carsharing respondents had a bachelor's degree (approximately 80%) and a large portion had a graduate degree (approximately 40%). Clewlow (2016) observed that more carsharing members had a least a bachelor's degree (38%) or graduate degree (45.5%) compared to the general population (33.7% had bachelor's degree and 35.8% had a graduate degree). Martin et al. (2021) also found higher levels of bachelor's degree attainment and post-graduate degree attainment compared to the general population estimates. Similarly, Shaheen, Martin, and Totte (2020) observed high levels of college attendance in their entire carsharing sample (approximately 84%).

2.2.1.4 Household Size

Carsharing members who lived in cities had smaller-sized households. Cervero and Tsai (2004) observed that City CarShare members tended to live with one or more unrelated adults (36.3%) compared to the general population of San Francisco households (17.4%). Less than half of City CarShare members lived alone (approximately 42%), slightly above the San Francisco average. The average household size for City CarShare members was 1.9 persons, slightly under the city average of 2.3 persons. Similarly, Martin and Shaheen (2011) found that the average household size for carsharing respondents was also 1.9 persons and was less than the United States average household size of 2.6 persons. Additionally, Lane (2005) found that most PhillyCarShare members lived alone or with a significant other (93%). The results of Cervero and Tsai (2004), Martin and Shaheen (2011), and Lane (2005) suggest that the majority of carsharing members residing in U.S. cities lived alone or with one other individual.

2.2.1.5 Income

In shared mobility research, income is often a variable of interest. In the papers reviewed, carsharing members were generally middle income. For example, City Carshare members had a median annual personal income of $57,000 (Cervero and Tsai 2004). Lane (2005) found that most (57%) PhillyCarShare members had annual household incomes between $25,000 and $75,000. Martin and Shaheen (2011) found that roughly the same proportion of carsharing members reported annual incomes of $30,000 to $40,000 and $40,000 to $50,000, with the median interval being $50,000 to $60,000. They estimate that half of the carsharing members in the sample had an annual income greater than $60,000. When comparing a subsample of carsharing members to a control group, Clewlow (2016) found that members making less than $74,999 were underrepresented compared to the general population, while incomes between $75,000 and $249,999 were overrepresented. Most carsharing members in the Bay Area had an annual household income of $100,000 or higher (59% of carsharing households vs. 37.2% of nonmember households). Shaheen, Martin, and Totte (2020) found that carsharing members were primarily middle income or higher, and underrepresented households made less than $25,000 (12% of carsharing members vs. 23% of the U.S. population). They also note that over a quarter of carsharing members had an annual household income greater than $100,000. Martin et al. (2021) also found less representation of lower-income households in the carsharing sample, while middle-income households were roughly the same across the carsharing sample and population estimates. However, households making above $100,000 were overrepresented, and approximately a quarter of respondents to the retrospective survey had an annual income of $200,000 or more. The proportion of high-income households marginally decreased in the before and after surveys.

Table 2. Carsharing Socio-Demographic Attributes

Source	Cervero and Tsai (2004)	Lane (2005)	Martin and Shaheen (2011)	Clewlow (2016)	Shaheen, Martin, & Totte (2020)	Martin et al. (2021): Retro-spective survey	Martin et al. (2021): Before survey	Martin et al. (2021): After survey
City(ies)	San Francisco	Philadelphia	Multiple North American cities*	San Francisco Bay Area	San Diego, Portland, Austin, San Francisco, Boston, New York, Boulder	New York City	New York City	New York City
n	462 (54 nonmem-bers)	262	6281	214–248; (928–1625 nonmembers)	1920 (1742 control)	2700	2700	2700
Age, years	36 y (median)	38.5 y (mean)	36.6 y (mean)	*16-20 y*: 1.5%	NA	*18-24 y*: 3.4%	*18-24 y*: 7.6%	*18-24 y*: 5.0%
				21-30 y: 12.9%		*25-34 y*: 28.6%	***25-34 y*: 38.6%†**	***25-34 y*: 35.9%†**
				31-40 y: 24.6%		***35-44 y*: 30.4%†**	*35-44 y*: 30.3%	*35-44 y*: 29.3%,
				***41-50 y*: 25.7%†**		*45-54 y*: 18.4%	*45-54 y*: 12.9%	*45-54 y*: 16.3%,
				51-60 y: 22.0%		*55-64 y*: 11.9%	*55-64 y*: 5.0%	*55-64 y*: 8.1%,
				61-70 y: 9.7%		*65-74 y*:6.0%	*65-74 y*: 4.6%,	*65-74 y*: 4.2%,
				≥71 y: 3.5%		*≥75 y*: 1.4%	*≥75 y*: 1.0%	*≥75 y*: 1.3%

Source	Cervero and Tsai (2004)	Lane (2005)	Martin and Shaheen (2011)	Clewlow (2016)	Shaheen, Martin, & Totte (2020)	Martin et al. (2021): Retro-spective survey	Martin et al. (2021): Before survey	Martin et al. (2021): After survey
Race/Ethnicity Carsharing (General Population Comparison)								
White	81.2% (49.6%)	89% (NA)	NA	NA	77% (62%)	57.3% (31.9%)	49.4% (31.9%)	51.1% (31.9%)
Asian					8% (5%)	9.0% (14.1%)	10.5% (14.1%)	9.9% (14.1%)
Hispanic/ Latino					7% (17%)	8.2% (29.2%)	16.9% (29.2%)	16.8% (29.2%)
African American/ Black					2% (12%)	8.5% (21.7%)	12.7% (21.7%)	12. 9% (21.7%)
Education Level	NA	99.6% (At-tended college)	80% (Bache-lor's) 40% (Gradu-ate)	83.5% (Bachelor's) [69.5% control]	84% (Bachelor's – working to-wards or com-pleted)	44.7% (Bache-lor's) 39.3% (Graduate)	39.4% (Bache-lor's) 32.1% (Graduate)	40.0% (Bache-lor's) 37.0% (Graduate)

Source	Cervero and Tsai (2004)	Lane (2005)	Martin and Shaheen (2011)	Clewlow (2016)	Shaheen, Martin, & Totte (2020)	Martin et al. (2021): Retrospective survey	Martin et al. (2021): Before survey	Martin et al. (2021): After survey
Annual Income	$57,000 (median personal)	$25,000–75,000 (57%) (household)	$50,000–60,000 (median household)	Middle to high income	<$25k: 12% $25k-$49,999: 23% $50k-$74,999: 17% $75k-$99,999: 12%-15% **≥$100k: 24%-28%†**	Middle to high income	Middle to high income	Middle to high income
Average Household Size	1.9 persons	Lived alone or with a significant other (93%)	1.9 persons	NA	NA	NA	NA	NA

*Cities: Toronto, CA; San Francisco, CA; Cleveland, OH; Bellingham, WA; Montreal, CA; Madison, WI; Vancouver, CA; Chicago, IL; Philadelphia, PA; Wilmington, DE; Ottawa, CA. And Zipcar

†Bold face type in these cells indicates the age range with the highest frequency.

2.2.2 Lack of Carsharing in Low-Income Communities of Color

Kim (2015) explored whether carsharing could meet the mobility needs for low-income neighborhoods in New York City (NYC). Kim's study used Zipcar's application programming interface (API) to collect vehicle utilization and location data across NYC neighborhoods. The study queried the API 30 minutes before the beginning of Zipcar's three-hour rental periods to capture an accurate representation of usage patterns. Vehicle rental prices and utilization vary, and thus researchers collected data over eight weekdays, four weeknights, and seven weekends to assess differences. In total, researchers identified 358 parking lots and 1,993 Zipcar vehicles in NYC as using Zipcar's API. The location of most Zipcar vehicles was in Manhattan (59.2%) and Brooklyn (26.7%), followed by Queens (7.9%), and lastly, Bronx (2.7%). The sample of Zipcar vehicles in NYC appears to represent the population, as there were a little over 2,000 vehicles operating in these boroughs in total. The study also used socio-demographic data from the 2007-11 American Community Survey and the 2011 Longitudinal Employer-Household Dynamics. Regarding typical usage patterns in NYC, Kim found that members used Zipcar more frequently in densely populated areas and public transportation-rich areas, like Manhattan. Additionally, during weekdays, Zipcar was highly used in business districts like lower Manhattan and on weeknights in residential areas, such as the outer boroughs (i.e., those other than Manhattan) and Hoboken/Jersey City.

Kim (2015) estimates Multiple Linear Regression models to assess Zipcar use patterns across time periods and neighborhoods. Kim identified low-income neighborhoods of interest, referred to as "Environmental Justice Neighborhoods" (EJN), by comparing NYC Housing Authority's public housing program income limit for 2012 and American Community Survey estimates of median family income and household size. Researchers labeled tracts as EJN if ACS estimates were lower than NYC Housing Authority's limit. Out of the 247 census tracts included in the study, researchers identified 66 tracts (26.7%) as EJNs that included 272 Zipcar vehicles, roughly 13% of cars in the sample. Kim found that members used Zipcar vehicles in EJNs more during weeknights, when rental prices were lower than weekdays and weekends. Additionally, members used vehicles in EJNs more than in non-EJ neighborhoods during weeknights. For example, members' use of Zipcar is above average in Queens (+9.6%) during weeknights and less than average during weekends (-3%). Weekend usage in the Bronx was also below average. Kim specifically linked this difference in usage to an issue of affordability, as rental prices were at their lowest during weeknights and highest during weekends. Overall, Kim argues that rental prices should remain low or subsidized when expanding services to low-income neighborhoods to meet carsharing demand in EJNs.

Tyndall (2017) researched the geographic locations of available Car2go vehicles in ten U.S. cities and compared the locations to census tract demographics. The cities included Austin, Columbus, Denver, Miami, Minneapolis, New York City, Portland, San Diego, Washington D.C., and Seattle. Vehicle location data was collected using Car2go's API, and the final data set contained 44,014,696 observations of available vehicles. Additionally, researchers obtained demographic information from the 2013 American Community Survey 5-year estimates for 1,728 census tracts. Using Ordinary Least Squares regression, Tyndall identified which census tract types were associated with high levels of access to Car2go vehicles. The model accounted for confounding factors such as census tract density, geographic size, and other city-specific characteristics. Researchers found an uneven distribution of Car2go vehicles within their "home zone," the geographic range for returning the carsharing vehicles. Instead, they found vehicles clustered in census tracts disproportionately populated by educated, young, employed, and white residents. On average, home zones accounted for 63% of the primary city's population and 16% of the metropolitan population. Across all ten cities included in the study, the most predictive demographic variable of vehicle availability was the percentage of 20 to 34-year-old residents in the census tract, followed by the rate of college completion. Tyndall found a statistically significant positive relationship between the availability of vehicles and the high school and college completion rates. Tyndall found no significant association between income level and vehicle availability. A potential methodological concern is the carsharing vehicle's cluster in the Central Business District, with particular demographic characteristics. Results show that vehicle availability is higher in census tracts disproportionately populated by young, white, educated, and employed residents.

2.2.3 Impacts of Carsharing Focused on Equity

As discussed in Section 2.1, Martin et al. (2021) studied the effects of a New York City pilot program that increased dedicated on-and off-street parking spaces for ZipCar and Enterprise CarShare vehicles in areas with traditionally low rates of carsharing. As described in Section 2.1, there was almost no improvement in the representation of non-white participants, education, and income after the pilot's implementation.

Randall (2011) describes the results of a retrospective survey of Buffalo CarShare members with responses from 134 members (33% response rate). Two-thirds of members report household incomes of less than $35,000. Members' racial diversity mirrors the neighborhood location of cars: 68% identified as White/Caucasian, 22% Black/African American, and 8% Hispanic. In addition, members represented a relatively balanced mix of young and older users: 28% of members were 50 or older, and 27% were under 30.

Rodier, Harold, and Zhang (2021) describe the interim results (August 2019 to May 2021) of the electric vehicles round-trip carsharing pilot, Miocar that offers a low-cost carsharing option for residents in rural underserved communities in the Central Valley of California. The pricing for Miocar includes a $20 member processing fee, a $4 hourly rental rate, a $35 daily weekday rental rate, and a $45-weekend daily rate. There is a 35 cent per mile fee after the vehicle travels 150 miles during one reservation. Preliminary results of surveys administered to members when they joined Miocar (with a 50% response rate) indicate that members belong to relatively large households (median household size 4.0 relative to median 3.6 in pilot areas based on ACS 2014-2018); most members have less education than an associate degree (62%); and most members fell into the low-income HUD[1] categories (35% extremely low incomes, 14%

[1] U.S. Department of Housing and Urban Development: Extremely low income: 0-30% of local area median income (AMI); Very low income: 30% to 50% of AMI; Lower income: 50% to 80% of AMI; the term may also be used to mean 0% to 80% of AMI; Moderate income: 80% to 120% of AMI (see https://www.hcd.ca.gov/grants-funding/income-limits/index.shtml)

very low income, 18% low income, 10% moderate-income, 14% high income, and 10% prefer not to answer). In addition, researchers administered post reservation surveys (50% response rate) to members upon completion of a vehicle reservation. The survey asked members about how they would have traveled without Miocar. The results indicated that 69% could not have traveled to their destinations without the Miocar service.

Mitra (2021) used data from the 2012 California Household Travel Survey to model the impact of carsharing on low-income households. The results indicated that low-income households are less likely than high-income households to use carsharing; however, when low-income households use carsharing, there is a significant impact on their mobility, particularly when combined with transit.

2.2.4 Equity Summary

We review studies of traditional carsharing services. These programs locate in densely populated neighborhoods with member bases primarily of young, white, upwardly mobile, affluent, educated individuals and households. The literature cited indicates that it may be possible for shared mobility to meet unique transportation challenges and needs of low-income neighborhoods, particularly if carsharing prices remain low or subsidized (Kim 2015; Shaheen 2020). While several shared mobility pilot programs aim to cater to traditionally underserved communities, limited research exists on how carsharing has effectively advanced transportation equity.

3. Short History of Carsharing in the U.S.

This section reviews the history of carsharing in the U.S. from 1998. In addition, this section aims to understand lessons learned that can inform funding and implementation of future publicly funded electric carsharing programs.

3.1 Overview

Early carsharing efforts in the U.S. were small and community-based, for example, the Dancing Rabbit Vehicle Cooperative in Rutledge (MO). In 1998, the first large-scale carsharing program in the U.S., CarSharing Portland, launched.

From 1998 to 2009 saw the development of numerous non-profit carsharing services dedicated to addressing barriers to access and environmental sustainability in the communities they serviced. Most served major urban areas, for example, City CarShare (San Francisco, CA), PhillyCarshare, IGO (Chicago, IL), and Hourcar (Twin Cities). Some, however, served smaller cities and rural areas, for example, Carsharing Vermont, Ithaca Carshare (NY), Colorado Carshare (Boulder, CO), and Buffalo Carshare. In addition, capital Carshare launched in Albany (NY) in 2013—a bit later than most non-profits.

In the early 2000s, two for-profit carsharing-focused companies emerged. In 2000, Zipcar launched in Boston and Cambridge. Flexcar initially focused on the West coast, acquired CarSharing Portland in 2001. They were the two largest carsharing companies when they merged in 2007. However, both received venture capital funds (AOL CEO Steve Case's Revolution LLC and Benchmark Capital), and Zipcar had yet to make a profit at the time of the merger (Shaheen et al. 2006).

The rental car company, Enterprise, entered the carsharing market in 2005, U-Haul and Hertz followed in 2007, and Avis in 2011 with its acquisition of Zipcar. In 2011, Enterprise acquired the for-profit Mint carsharing service, PhillyCarShare, and IGO. Meanwhile, Zipcar/Avis acquired Community Carshare (Madison, WI) and Buffalo Carshare in 2015. A review of publicly available location data since the acquisition of these non-profit services by Enterprise and Avis indicates that significant service cutbacks occurred in less profitable low-income communities of color. In contrast, service consolidated in profitable markets typically in dense high-income areas with high-quality transit and on or near college campuses. Published studies by Kim (2015), Tyndall (2017), Mitra (2021), and Kodransky and Lewenstein (2014) confirm these observations.

The peer-to-peer carsharing model launched in 2011 with Getaround has grown rapidly since then. This model allows car owners to rent their vehicles to others. The operator facilitates rentals through mobile phone apps and websites. Today, the two largest peer-to-peer carsharing services are Getaround and Turo (which provides only daylong or multi-day rentals). Since the pandemic, both companies have rebounded and are pursuing listings as public companies as of fall 2021 (Alamalhodaei 2021; Hu 2021).

The emergence of ridesharing and the prospect of driverless cars fueled speculation that new technology could make both car ownership and drivers obsolete. In the 2010s, automakers began experimenting with carsharing led by Daimler's Car2Go, which entered the U.S. market in Austin in 2010. Car2go, once considered the largest carsharing network globally, operates in nine countries and nearly 30 cities (Martin and Shaheen 2016). Four years later, GM's Maven and BMW's ReachNow launched in 2016. Car2Go and ReachNow merged in 2019 as ShareNow. Maven and ShareNow shut down their carsharing services in 2020 before the pandemic due to difficulties operating in the North American market, such as a lack of infrastructure to support electric vehicles (The Seattle Times 2020). However, ShareNow continues to operate successfully throughout Europe. Hyundai, the most recent automaker to enter the space, launched a 100-vehicle carsharing service called Mocean in Los Angeles in 2020 that shut down just over one year later at the end of 2021.

More recently, federal, state, and local agencies have begun funding and supporting pilots that address climate change by implementing electric carsharing and EVSE (electric vehicle service equipment) and locating these services in underserved communities at an affordable cost. The latter funding programs address the concern that carsharing and other shared mobility services have largely left behind low-income communities of color, as well as the concern that EV incentives have primarily benefited affluent households. BEV carsharing may increase affordable mobility without increasing GHG emissions and, perhaps, even reduce GHGs by substituting for conventional vehicle travel. Another potential benefit is that exposure to BEV vehicles and the availability of infrastructure may encourage a more rapid uptake of BEVs as personal vehicles.

California uses cap-and-trade Climate Investment funds to develop BEV carsharing in affordable housing communities in Sacramento (Our Community CarShare) and rural areas of Tulare and Kern counties in the Central Valley (Miocar), and one-way carsharing in Los Angeles (BlueLA). New pilots are launching in the Bay Area and Stockton (Miocar expansion). Furthermore, cap-and-trade funds distributed through the 2020 Clean Mobility Options program have also found their way into two indigenous communities (Twenty-Nine Palms Band of Mission Indians and the Cahuilla Band of Indians).

California also permitted Volkswagen (VW) to use a share of settlement funds from the "dieselgate"[2] scandal to support BEV carsharing in Sacramento: $44 million funded BEV point-to-point carsharing in the central city area of Sacramento (GIG carsharing owned by AAA) and BEV carsharing as a housing amenity (Envoy Technologies) in underserved areas[3] of the city. In addition, part of the $44 million also went to fund ten direct-current fast chargers (Electrify America 2018).

New York and Massachusetts have funded programs similar to California's Clean Mobility programs, albeit at a smaller scale. The Federal Department of Energy has also funded BEV carsharing programs in Portland (Hacienda), rural Oregon (CRuSe), and the Twin Cities' Evie

[2] The VW "dieselgate" began when VW made the decision to use illegal "defeat device" software to bypass emissions control equipment in order to create the appearance that its cars met California and U.S. health-based air quality standards.

[3] As classified by the State of California CalEnviroscreen 3.0

expansion of HourCar. In addition, the federal government invested CARES Act funds in Colorado to fund BEV carsharing in underserved communities.

The new wave of support for carsharing to reduce GHG emissions and support mobility in underserved communities raises interest in the scale and sustainability of non-profit carsharing in the past and present. In section 3.2, below, we describe the size and years of non-profit carsharing and discuss their plans for expansion with new funding opportunities. Many of these non-profit programs had social and environmental goals. Section 4 focuses on pilots, demonstrations, and programs funded by grant programs that intend to increase the uptake of electric vehicles to reduce GHGs and address accessibility disparities in underserved communities.

3.2 Non-Profit Carsharing

As discussed above, several carsharing organizations began as non-profits. For-profit companies then acquired them. The San Francisco non-profit, City Carshare, one of the first shared mobility options in the Bay Area, launched in 2001. In 2016, City CarShare reached a deal with Getaround, the peer-to-peer car rental platform, to take over the non-profit's parking spaces, fleet, and member base. At the time of acquisition, CityCarshare had approximately 20,000 active members and a 200-vehicle fleet (Creely 2016). Records indicate that City Carshare may have peaked at about 340 vehicles in 2011 (Siu 2016). According to the San Francisco Chronicle, City CarShare faced fundraising challenges and heavy competition from venture-backed rivals, which ultimately led to partnering with Getaround (Said 2016). See Table 3 for a comparison of non-profit carsharing programs in the U.S.

Enterprise acquired several non-profit carsharing services in major urban areas. Enterprise Holdings purchased PhillyCarShare (located in Philadelphia, Pennsylvania, and Wilmington, Delaware) in 2011. PhillyCarShare operated as a non-profit beginning in 2002. The parent company rebranded Enterprise carsharing as Enterprise CarShare in 2013 (Fisher 2013). Before the acquisition, PhillyCarShare had a 400-vehicle fleet at its peak in 2009 (Fernandez 2011). At the acquisition time, Philly CarShare had over 13,000 members (Enterprise Holdings 2011). Reports indicate that the acquisition of Philly CarShare resulted from a debt of $2.7 million in back taxes and penalties (Fernandez 2011). Next, Enterprise CarShare purchased IGO CarSharing in Chicago, Illinois, and AutoShare in Toronto, Canada, in 2014 (CNT; Keenan 2014). In 2013, IGO's had 250 vehicles and 15,000 members (Wernau 2013). At the time, these non-profits indicated that for-profit companies might be better positioned to expand services and increase awareness of carsharing (Said 2016; CNT).

The Buffalo CarShare program operated from 2009 to 2015 in Buffalo, New York (Gottlieb 2015; Drury 2015). During its operation, members completed roughly 35,000 trips using this service. According to a 2015 article, half of its active members were people of color with a household income of less than $25,000 per year. By the end of its operations in 2015, Buffalo CarShare had 900 registered members sharing a fleet of 19 vehicles. Unfortunately, the high cost of insurance coverage in New York ended its non-profit operations, and Avis/Zipcar acquired the non-profit (Randall 2011).

Capital Carshare launched in Albany, NY, in 2014. This carshare program received funding from the Capital District Transportation Committee and a Community Loan Fund. Unfortunately, several accidents resulted in an increase in insurance premiums, which was unsustainable at the scale of an eight-car program and was one factor that led the carsharing service to end all operations at the end of 2020 (Karlin 2020). During the six years of operation, Capital Carshare's fleet fluctuated between 6 to 10 vehicles, including conventional and electric vehicles.

Ultimately, three non-profit carsharing services continue to serve their local communities today. Hourcar, in the Twin Cities, launched in 2005, and Ithaca Carshare and Carsharing Vermont launched in 2008. However, member revenues sustained IGO, City CarShare, and Buffalo CarShare for several years. PhillyCarShare received a significant grant that supported the operations, and thus, it is unclear to what degree revenues sustained their operations.

Since 2005, Hourcar has operated its round-trip service and includes over 50 conventional and HEVs. The program launched in the Twin Cities and expanded to Rochester, Minnesota, in late 2019 (Baker 2019). Currently, the service has 42 locations along Interstate-94 and near Minneapolis and St. Louis (Melo 2021).

Formally known as eGo, Colorado Carshare has roots in the Little Red Car Co-Op, launched in 1997. Co-op members would physically transfer the vehicle keys and share one vehicle in North Boulder, Colorado (Tidd 2013). Federal funding has enabled Colorado Carshare to expand operations. In 2009, Colorado Carshare received a Congestion Mitigation and Air Quality (CMAQ) grant to expand from three to thirty carsharing sites in Denver. Another CMAQ grant allowed Colorado Carshare to expand carsharing sites to nearby B-cycle (bikeshare) sites for first and last-mile transit access in Denver and Boulder (Colorado Carshare 2021). Today Colorado Carshare operates as a non-profit carsharing program in both Denver (30 sites) and Boulder (24 sites) with more than 50 vehicles in their fleet, which includes conventional, BEV, HEV, and all-wheel drive vehicles (Colorado Carshare 2021). It also provides discounted rates for low-income members. According to tax documents comparing revenue in 2017 to 2014, Colorado Carshare's revenue declined in 2017 compared to 2014 levels when revenue peaked. Ride-hailing may have impacted revenues (Bosselman 2019). In 2020, Colorado Carshare used Federal CARES Act funds to expand BEV carsharing in underserved communities in six new sites (DOCA 2021).

In 2006, Ithaca Carshare obtained funding from the New York State Department of Transportation and the New York State Energy Research and Development Authority (NYSERDA). Ithaca Carshare launched later in 2008 with six hatchback vehicles. It operates in downtown Ithaca, Collegetown, Fall Creek, Northside, and the West End. The current fleet includes 29 vehicles, two of which are BEVs, and serves over 6,000 members (Ithaca Carshare Member Handbook 2021). Ithaca Carshare operates under an umbrella organization known as the Center for Community Transportation. The Center for Community Transportation also includes Bike Walk Thompkins and Backup Ride Home. Bike Walk Thompkins facilitates the Lime Bikeshare program and conducts outreach and education to promote active transportation. The

Back-Up Ride Home guarantees anyone who commutes to work by carpool, transit, walking, or biking a convenient way to leave work due to unexpected events.

Carshare Vermont launched at the end of 2008 with an eight-vehicle fleet in the Burlington, Vermont area (Bourdon 2011). Today the program has a 21-vehicle fleet, including four electric vehicles (CarShare Vermont 2021). In 2020 Carshare Vermont, played an active role in guiding the City of Burlington to eliminate parking minimums (i.e., the requirement that an apartment provide a minimum number of parking spaces) (Carshare Vermont 2020). In 2020, Carshare Vermont launched an electric vehicle pilot program (Carshare Vermont 2021). In 2021, Carshare Vermont received a $100,000 grant from the Vermont Agency of Transportation to develop an electric vehicle supply equipment (EVSE) network at affordable housing developments within the City of Burlington (VTrans 2021).

Table 3. Summary of Non-Profit Carsharing Services in the U.S.

Name	Cities	Years Operational	Service Type	Vehicles	Sites
eGO	Denver, Bolder (CO)	1997-present	One-Way	50 + HEV, BEV, ICEV	NA
City Carshare	San Francisco, Oakland, Berkeley, Palo Alto (CA)	2001-2016	Round Trip	380 BEV, PHEV	180
Philly Carshare	Philadelphia (PA)	2002 - 2011	Round Trip	450 (50% HEVs)	150+
iGO	Chicago, Evanston (IL)	2002-2013	Round Trip	185 ICEV, PHEV, HEV	200
Hourcar	Minneapolis (MN)	2005-present	Round Trip	50 ICEV, HEV	40
Buffalo Carshare	Buffalo (NY)	2007 - 2015	Round Trip	23 ICEV, HEV, BEV	NA
Ithaca Carshare	Ithaca (NY)	2008-present	Round Trip	29 HEV, ICEV, BEV	30
Carshare Vermont	Burlington (VT)	2008-present	Round Trip	21 BEV, ICEV	19
Capital Carshare	Albany, Troy (NY)	2014-2020	Round Trip	10 ICEV, HEV, BEV	3

Abbreviations: internal combustion engine vehicle (ICEV); hybrid electric vehicle (HEV); plug-in electric vehicle (PHEV); battery electric vehicle (BEV)

4. New Wave Carsharing with Social and Environmental Goals

This section categorizes a wave of carsharing programs that use electric vehicles and aims to increase access in underserved communities. The first category is public programs initiated and supported by cities, counties, or regions with the explicit intention of providing an enduring public service. The programs are funded almost entirely with public dollars and use private or non-profit operators. The second category includes pilots/demonstrations with public funding. These pilots/demonstrations receive funds from a public agency to test specific goals. Private carsharing companies manage the operations of the program with minimal oversight. As a result, there is minimal long-term investment in the success of the pilot/demonstration as a program from the public partner. The third category includes privately led public-private partnerships. Privately administered and sponsored, these projects may receive grant money and/or public space. However, outside of the conditions of their grants and public space agreement, these programs are independent of public oversight. In the sections below, we describe the programs in each category with information about dates of operations, goals, funding sources, type of carsharing services, and the number of vehicles and sites. It is important to note that this section is descriptive and focuses on sustained operations because there is little evidence of their outcomes (unless otherwise noted).

4.1 Public Programs

We include BlueLA (Los Angles), Our Community CarShare (City of Sacramento), Miocar (San Joaquin Valley), and Evie (Twin Cities) in the public programs category. See Table 4 for a summary of these programs. Again, these are public programs initiated and supported by jurisdictions to provide an enduring public service and are funded almost entirely with public dollars and use private or non-profit operators.

BlueLA was initially another venture from the Bollore group[4] that launched in 2017. Los Angeles (LA) received $2.8 million from the California Greenhouse Gas Reduction Fund. It also received an additional $10 million in private funds from BlueLA (Shared-Use Mobility Center 2019). BlueLA began operating its point-to-point service in Central LA with a 100 EV Fleet and 200 electric vehicle charging stations in Phase 1 of the program. The program included standard and reduced community rates (45% off the standard rate) for low-income residents who must document their income or document participation in other low-income programs. As the program enters Phase 2 and 3, the City of LA has entered into a contract or agreement with Blink Mobility to take over the BlueLA service in 2020 (Blink Charging Company 2020). As of October 2021, Blink received approval from the City of Los Angeles to expand the service to

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[4] The Bollore Group is a French based company that deploys zero-emission point-to-point carsharing. The company deployed its point-to-point operations outside the U.S. in urban areas such as Paris (Autolib), Lyon (BlueLy), Bordeaux (BlueCub), Singapore (BlueSG), and London (BlueCity). (Reuters, 2014; Reuters, 2016) The electric vehicle of choice for all Bollore carshare operations was the Bollore Bluecar, which had a 155-mile range and 33 kWh battery (Bollore Group).

include 300 curbside EVSE and 200 EVs. CARB and the City of Los Angeles contributed public funds in expanding the service. (Blink Charging Company 2020)

In Sacramento, Our Community CarShare launched in May 2017. This program is unique because it does not charge the user and thus does not generate revenues. Members are verified residents of affordable housing communities across the City of Sacramento. Approved members have access to BEVs, which they can use up to 3 hours per day or 9 hours per week, completely free of charge. The program currently includes 22 PHEVs and BEVs and 22 EVSE charging stations. This program employs a round-trip model that requires a modified ZipCar website or ZipCar mobile application to access the vehicles. The program locates vehicles at affordable housing (Personal Communication 2020b).

Míocar is round trip carsharing located at eight affordable housing developments in six rural underserved communities in the southern Central Valley of California (Tulare and Kern counties). Residents living inside and outside the affordable housing developments are free to use the service—the program launched in May of 2019 with support from California's Climate Change Investment Fund. The service includes 27 EVs with ranges that are suitable for rural driving. The program purchased many of these vehicles used, with less than 30,000 miles. The pricing for Míocar includes a $20 member processing fee, a $4 hourly rental rate, a $35 daily weekday rental rate, and a $45-weekend daily rate. In addition, there is a 35 cent per mile fee after the vehicle travels 150 miles during one reservation. The pilot resulted in the development of a non-profit operator poised to expand EV carsharing in Kern County and the cities of Richmond and Stockton with additional funding from the Climate Change Investment Fund.

Hourcar, operating since 2005, includes internal combustion engine vehicles; however, through a collaboration with Xcel Energy, HourCar is expanding its service to include free-floating BEV carsharing (Journal 2021). Hourcar will expand from 60 vehicles to include an additional 150 EVs. The program, called Evie, is one of three key aspects of the Twin Cities Electric Vehicle Mobility Network (Melo 2021). The Twin Cities Electric Vehicle Mobility Network project received $12 million in public and private funds to include publicly available EVSE (DCFC and L2). The program locates EVSE at 70 charging hubs, which will be available for both shared Evie vehicles and for public charging (St. Paul 2020). Furthermore, the plan includes locating EVs at multi-family housing developments (US DOE 2020). Numerous sources pooled funds including, St. Paul ($750,000), Minneapolis ($350,000), the Federal Congestion Mitigation Air Quality Improvement Program ($4 million), US DOE ($3.3 million), and Xcel Energy ($4 million) (Melo 2021). The program locates the new BEVs in historically marginalized communities of St. Paul and Minneapolis (Journal 2021). The updated service will employ both a free-floating zone and a round-trip model for its fleet of BEV Chevrolet Bolts. However, the Chevrolet Bolt recall[5] had delayed the implementation of the program.

Table 4. Summary of Public Programs

Name	City	Years Opera-tional	Goals	Funding	Service Type	Vehicles	Sites
BlueLA	Los Angeles (CA)	2018-present	GHGs and access equity	City of LA with CCI funds	One-way	100 BEV (2020); 300 BEV (2022-23)	200 EVSE, 40 sites (2020); 500 EVSE, 100 sites (2022-23)
Our Community Carshare	Sacramento (CA)	2018-present	GHGs and access equity	Sacramento Air Quality Management District with CCI funds	Round-trip	22 PHEV and BEV	At least 22 EVSE
Miocar	San Joaquin Valley (CA)	2019-present	GHGs and access equity	San Joaquin Valley Air Pollution Control District and Kern, Tulare, and San Joaquin MPOs with CCI funds	Round-trip	27 BEV, PHEV (2020); 95 BEV, PHEV (2022)	28 EVSE, 8 Sites (2019); 120 EVSE, 50 sites (2022-23)
Evie	Minneapolis (MN)	Under develop-ment	GHGs and transit gaps	Non-profit HourCar with DOE funding	Free-floating	150 BEV	280 EVSE, 70 Sites

battery electric vehicle (BEV); Climate Change Investment Fund (CCI); Department of Energy (DOE): electric vehicle supply equipment (EVSE); hybrid electric vehicle (HEV); metropolitan transportation organizations (MPOs) plug-in electric vehicle (PHEV);

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[5] General Motors has announced a recall to all Chevrolet Bolt models (2017-2022) due to hardware and software issues resulting in spontaneous battery fires. Specifically, fires can occur while the vehicle is charging or if the battery is depleted past a certain point. As of October 2021, it is unknown how General Motors will address these defunct vehicles. (General Motors, 2021)

4.2 Pilot/Demonstration with Public Funding

We include Car2Go (San Diego), BlueIndy (Indianapolis), Green Commuter (Chattanooga), and Envoy (Electrify America Green City in Sacramento). See Table 5 for a summary of these programs. Again, this category includes pilots/demonstrations that receive funds from a public agency to test specific goals with private carsharing companies managing operations.

From 2011 to 2016, Car2go operated a one-way carshare program in San Diego with 300 Smart ForTwo vehicles with Federal Highway Value Pricing Program Funds to test pricing incentives to optimize the recharging of the fleet. The fleet was initially electric; however, the charging infrastructure needed to support the fleet never fully materialized. In addition, the program installed only 400 of the 1,000 planned EVSE stations due to the bankruptcy of the non-profit handling the installations (San Diego Union-Tribune, 2016). While Car2go's services in San Diego had positive outcomes, such as a large member base and reduced GHG emissions. Over time, however, the membership numbers plateaued, and use declined. As a result, car2go stopped serving nearly half the neighborhoods it had previously occupied to account for these issues. Car2go eventually converted the BEV fleet to gasoline-powered vehicles. Six months after this fleet conversion, Car2go pulled their services from San Diego entirely (San Diego Union-Tribune 2016). This shift in operation affected the San Diego regional planning organization's plans to expand the service into Barrio Logan, a predominantly Latino underserved community, with funding through a Climate Change Investment grant (Personal Communication 2020c).

According to interviews with the San Diego Metropolitan Planning organization's personnel, Car2Go in San Diego faced several challenges. One of the key issues of this project was a hands-off approach taken by the City of San Diego, which resulted in a lack of coordination and missed opportunities (Interview 2020). Lapses in communication made enforcement agencies unaware of the parking regulations for carshare vehicles, and they often cited or towed legally parked Car2go vehicles. In addition, non-carsharing vehicles often occupied parking restricted to Car2Go vehicles. Ultimately, the program served as an amenity for vehicle owners rather than an attractive alternative to vehicle ownership. In short, San Diego Association of Governments suggests that projects like Car2go be considered a public service, to which a substantial amount of resources, financial and personnel, can be allocated (Interview 2020a).

In 2015, Bollore expanded its zero-emission point-to-point carsharing operation in Indianapolis, known locally as BlueIndy. BlueIndy was the most extensive point-to-point, zero-emission vehicle carsharing operations in the U.S. market at the time of its launch. BlueIndy's fleet peaked at approximately 280 EVs with over 3,000 members (Lambert 2020). Unfortunately, BlueIndy ended its operation at the end of May 2020 due to the financial infeasibility of the business (Berman 2019). The City of Indianapolis is currently deciding what to do with the 80 or so EV charging stations left in the right-of-way by the carshare operation. The City has left it up to local citizens to decide what to do with the electrical infrastructure (Pak-Harvey 2020).

After receiving $750,000 from the Chattanooga Area Regional Transportation Authority, Green Commuter Chattanooga began its service. The funding provision went towards the purchase of 20 BEVs (Nissan Leaf) and 20 charging stations (Businesswire 2016). The vehicles, stationed at solar-arrays, were to be powered with renewable energy. The project was implemented by Green Commuter, Tennessee Valley Authority, Prova Group (transportation planning firm), and the Chattanooga Area Regional Transportation Authority (EPB 2018). The project's goal was to enhance transit service and support multi-modal transportation (Descant 2018b).

Envoy Technologies provides a round-trip mobility carsharing platform that initially provided 142 Volkswagen E-Golfs as an amenity for 71 multi-unit dwelling locations in Sacramento (Electrify America 2018). The vehicles are only accessible to residents living at the property. Originally, 75% of Envoys locations were planned in priority communities in the City of Sacramento. In Quarters 1 and 2 of 2021, Envoy operated at 45 residential properties with 90 BEVs, and in Quarter 2, only 71% of locations served priority communities. Envoy unilaterally removed 42 vehicles in service. As a result, according to the 2021 Quarter 2 Electrify America Report to CARB, Envoy currently serves 45 properties with 90 electric vehicles. Envoy still has at least one vehicle at all 45 properties. The fate of the vehicles removed from service is unknown. The reason behind the removal of the vehicles is unknown; however, the explanation may be COVID-19 and lack of utilization. (Dick 2021)

Table 5. Summary of Pilot/Demonstration with Public Funding

Name	City	Years	Goals	Funding	Service Type	Vehicles	Sites
Car2GO	San Diego (CA)	2011-2016	Pricing to optimize EVSE	U.S. DOE and CA ZEV Credits	Free-Floating	300 BEV	400 spaces
BlueIndy	Indianapolis (TN)	2015-2020	GHGs	City and Bollore Group	One-way	282 BEV	89 EVSE
Green Commuter	Chattanooga (TN)	2016-2019	GHGs and transit gaps	TVA, EPB, City Transit	Round-trip	20 BEV	20 sites
Envoy, Electrify America Green City	Sacramento (CA)	2019 - present	GHGs and equity access	Electrify America, California Energy Commission	Round-Trip	142 BEVs (2018); 48 BEVs (2021)	45 EVSE, 45 sites

battery electric vehicle (BEV); Department of Energy (DOE); Electric Power Board of Chattanooga (EPB); electric vehicle supply equipment (EVSE); , Tennessee Valley Authority (TVA)

4.3 Privately-Led Public-Private Partnership

We include Car2Go (San Diego), BlueIndy (Indianapolis), Green Commuter (Chattanooga), and Envoy (Electrify America Green City in Sacramento). See Table 6 for a summary of these programs. Again, this category includes privately administered and sponsored projects that may receive grant money and/or public space but are largely independent of public oversight.

An early example is the Hacienda community carsharing pilot in the predominantly underserved, minority community of Cully (Portland). Forth, a non-profit elective vehicle advocacy group, and Hacienda CDC, a non-profit advocacy group for the Cully community, launched the all-electric peer-to-peer carshare program in 2017, providing Cully neighborhood residents with 3 Honda Fit EVs located at Hacienda CDC headquarters (Forth 2018). The Community electric carshare program operated from March 2017 until December 31, 2017 (Forth 2018). During its eight months of operation, the service received 108 reservation requests and completed 66 vehicle reservations for its two community vehicles (Forth 2018). The third vehicle was an employee vehicle for Hacienda CDC employees that tracked 1,914 vehicle miles driven while saving $1,023.99 on their transportation expenses (Forth 2018). Initially, the pilot planned to use the carsharing platform available in the Portland city core; however, this platform could not be extended to the Cully neighborhood (Interview 2020b). As a result, project managers used a third-party peer-to-peer application, Turo (Forth 2018), which required an in-person exchange of vehicle keys. However, the logistics and administration of the Turo application posed challenges for program managers, which often resulted in missed reservations (Forth 2018). Program managers also highlighted the importance of hosting informational learning sessions for the public to understand the application, reservation process, and vehicle technology (Personal Communication 2020a)

The Clean Rural Shared Electric Mobility or CRuSe pilot began operating in the summer of 2021 in Hood River, OR. Forth developed this program (Forth 2021). Other partners include EV infrastructure developers (OpConnect), carshare platform operators (Envoy Technology), and local utility provider (Pacific Power). Residents and visitors of Hood River have access to five Honda Clarity vehicles stationed at the city center, affordable housing sites, and tourist destinations (Forth 2021). This carshare program employs a round-trip model. By strategically distributing vehicles in the service area, program managers hope to attract a wide range of users, including tourists, government workers, and small-town residents. The CRuSE pilot has a tiered pricing platform suited to the three markets (Personal Communication 2020a). Additionally, this allows for alternate forms of payment, including a cash option, to improve accessibility for all communities of Hood River.

AAA operates GIG CarShare, a free-floating carsharing model that serves the San Francisco Bay Area, Seattle, and Sacramento. At the time of its launch in Sacramento in 2019, it was the nation's largest all-electric carshare fleet (Anderson 2019). Initially, GIG Carshare operated a fleet of 260 Chevy Bolts in a 13 square mile radius around Downtown Sacramento. Just six months after the launch, GIG expanded the extent of its home zone in Sacramento by 30% to include portions of East and South Sacramento (Hamann 2019). Those living within or near the GIG home zone have a clear geographic advantage to BEV access compared to other communities outside the home zone. GIG Carshare also includes hybrids. GIG CarShare vehicles can travel between Sacramento and the Bay Area but return to their home zones (Anderson 2019). In response to the COVID-19 pandemic, GIG changed its service model to allow for multi-day rentals (consecutive). According to the Quarter 2 2021 Electrify America Report to the California Air Resources Board (CARB), the service has seen its highest utilization in a single quarter since the service was implemented. Compared to pre-pandemic usage (Q1 2020), 110% more miles were driven in Q2 2021. (Electrify America 2021).

MoceanLabs is a company led by Hyundai Motor Group and has been operating Mocean Carshare since late 2019 in distinct zones across the City of Los Angeles (Hyundai 2019). The pilot program launched with a small fleet of 20 Hyundai IONIQ Plug-in Hybrid Electric vehicles but has since expanded to include EVs from other manufactures. With the city’s sights set on the 2028 Olympic Games, Mocean plans to reach an all-electric vehicle fleet of 300 vehicles, with the goal of improving congestion for residents and visitors of Los Angeles. Currently, Mocean operates vehicles located in four home zones, including Downtown LA, Eagle Rock, communities in West Los Angeles, and the San Fernando Valley.

The COVID-19 pandemic posed early challenges that forced Mocean Labs to reconsider its deployment strategy. Instead of having some of the vehicles garaged, these were offered to the USC “Street Medicine” team to provide critical health check-ups during the pandemic to people in homeless encampments and under freeway overpasses (Bloomberg 2020). The program closed at the end of 2021.

Table 6. Summary of Privately Led Public-Private Partnerships

Name	City	Years	Goals	Funding	Service Type	Vehicles	Sites
Hacienda	Portland (OR)	2017	GHGs and access equity	DOE to non-profits	Peer-to-Peer	3 BEV	3 sites
Gig Carshare, Electrify America Green City	Sacramento (CA)	2019-present	GHG and access	Electrify America, City of Sacramento	Free-Floating	260 BEVs	13 square mile radius
Mocean	Los Angeles (CA)	2019-2021	Improved Access	Hyundai	One-way	100 BEV, HEV and PHEV	N/A
CRuSE	Hood River (OR)	2020-present	GHGs and access equity	DOE to non-profits	Round-trip	5 BEV	5 sites

hybrid electric vehicle (HEV); plug-in electric vehicle (PHEV); battery electric vehicle (BEV)

5. Summary and Conclusions

Over the last six years, from 2016 through 2021, a wave of new federal, state, and local funding has supported carsharing services that use electric vehicles and install electric vehicle chargers to reduce GHG emissions and address climate change. In addition, most of these funding programs allow support for the location of services in underserved communities with affordable fares. As described above, the goal of this study is to help inform the design and improve the value of investments in future electric carsharing programs (1) by reviewing the academic literature that evaluates the travel, GHG, and equity effects of implemented carsharing programs in the U.S. and (2) by analyzing the evolution of carsharing in the U.S., including non-profit, for-profit, and recent government-funded carsharing, to glean insights and identify unanswered questions about government electric carsharing investments. The following are lessons learned relevant to this new wave of funding and projects.

Lesson Learned #1: Carsharing, especially with electric vehicles, is likely to reduce GHG emissions.

The academic literature review that evaluates U.S. carsharing programs from 2004 to 2021 shows reductions in vehicle miles traveled and associated GHG emissions, especially for round-trip carsharing, based on self-reported pre-and post-carsharing surveys. The evaluations also suggest that carsharing members often decreased vehicle ownership and forwent the purchase of an additional vehicle. Furthermore, the studies indicate that round-trip carsharing does not reduce transit use. In some cases, it increases, often serving to complement trip types and destinations that are more challenging to serve with fixed-route transit. The use of electric carsharing would tend to further increase GHG reduction benefits compared to conventional vehicle carsharing.

Lesson Learned #2: Private carsharing services are likely to limit service to urban areas with high demand where residents can pay the market rate fares.

Our review of the evolution of carsharing services in the U.S., not surprisingly, shows that commercial carsharing services locate their services where they can make a reasonable profit for their efforts. Such locations have high usage rates by members who can afford profit-making fares. Private sector companies, whose sole business was carsharing (such as Mint and the original Zipcar), were acquired by rental car companies. In the U.S. today, non-peer-to-peer carsharing is primarily operated by rental car companies, and carsharing is part of a diversified business model.

Our literature review shows that private sector carsharing tends to be in major metropolitan urban areas with high-quality transit and in neighborhoods where residents are affluent (median to high incomes), highly educated, young (late 20s to early 40s), and white. In addition, reviews of the publicly available location data since the Enterprise and Avis acquisitions indicate significant service cutbacks occurred in less profitable low-income communities. In contrast, service was consolidated in profitable markets, typically in dense high-income areas with high-quality transit and on or near college campuses. Moreover, published studies by Kim (2015), Tyndall (2017), Mitra (2021), and Kodransky and Lewenstein (2014) confirm that the geographic distribution of services and service costs have been key barriers to access of carsharing among marginalized populations.

Lesson Learned #3: In the short term, private sector carsharing will likely continue to use conventional or hybrid vehicles.

There is no example of a commercially successful electric carsharing program to date because of the lack of developed and consistently reliable electric vehicles and infrastructure. Three automakers, Daimler, GM, and BMW, launched major carsharing initiatives in the U.S., including some electric vehicle fleets, and, in 2020, each shut down operations nationwide. Where these operators piloted electric carsharing, such as the Car2go (Daimler) program in San Diego, these electric vehicle-dependent markets were some of the first to close due, in part, to challenges with electric vehicles and infrastructure. Hyundai, the most recent automaker trying to make a go of carsharing services in Los Angeles, announced in fall 2021 that it would end services by the end of the year before even bringing electric vehicles into their fleet mix. The exception is GIG carsharing, funded by AAA, which uses electric vehicles in Sacramento. However, VW settlement funds subsidized the electric vehicles and infrastructure. Until electric vehicles become competitive with hybrid sedans and charging infrastructure becomes more widespread, subsidies for electric vehicles and charging infrastructure for carsharing services are critical to reduce operational risks. As such, cities will be challenged to attract these larger private sector partners to small-scale pilots in disadvantaged communities that lack this infrastructure and are often not proximal to their preferred market. In other words, the combination of EVs with the prioritization of low-income communities presents a barrier to entry for a retrenched private sector in this industry.

Lesson Learned #4: Non-profit carsharing continues to be feasible in the U.S. and may be one approach to expanding service beyond the service boundaries of private sector carsharing.

This study suggests that sustainable local non-profit carsharing programs that address environmental and social goals in their community are possible inside and outside of major urban areas. For many years, non-profit carsharing operated at a large-scale in major metropolitan areas (e.g., San Francisco Bay Area, Chicago, and Philadelphia). However, the emergence of ride-hailing companies in 2010 and the dominance of for-profit carsharing services run by rental car companies from 2010 to 2012 preceded the decline in non-profit carsharing. In addition, rental companies acquired many non-profit carsharing services. Nevertheless, four long-established non-profit carsharing programs continue to provide services in large and small urban areas and are largely self-sustaining. Representatives from two of these programs, Ithaca Carshare and Carshare Vermont, were interviewed as part of this study and reported that 1% to 20% of non-profit carsharing revenue typically comes from private or government contracts. In addition, service can expand with an infusion of public funds (as in Colorado and the Twin Cities).

Lesson Learned #5: In recent years, public or community-controlled electric vehicle carsharing projects show progress towards effectively increasing equity of access in marginalized populations, as measured by these programs' ability to sustain operations.

We reviewed 12 projects supported by the new wave of carsharing programs, which included the use of electric vehicles and/or low-cost services in underserved communities. We categorized these programs and described their progress.

Public or Community-Controlled Programs: The first category of projects includes four public programs initiated and supported by cities, counties, or metropolitan regions with the explicit intention of providing an enduring public service. Most of these programs range in scale from large (Los Angeles at 100 current and 300 planned electric vehicles), to moderate (San Joaquin at 27 current and 95 planned electric vehicles and Twin Cities at 150 planned electric vehicles), and to small scale (Sacramento at 22 electric vehicles). All four programs have recently launched and/or are expanding operations. The Los Angeles and Sacramento programs have relationships with vendors that own the electric vehicles and operate the carsharing service. Miocar and Hourcar are non-profits that own electric vehicles and operate their carsharing service in-house. All programs address issues of affordability with below-market-rate pricing. Carsharing services are almost exclusively located in underserved communities and often with affordable house developments. The programs are funded mainly through public investments. The California Air Resources Board (CARB) and the U.S. Department of Energy (DOE) are the two largest investors in these models. As an exception, the BlueLA program in Los Angeles secured significant private funding commitments in the program's first and second phases.

Public-Private Demonstrations: This includes pilots/demonstrations with public funding. These programs receive funds from a public agency to test specific goals and typically originate from a pre-existing public-private partnership formed before the investment of public funding. Private carsharing companies manage the program's operations with varying degrees of public oversight. As a result, the investment tends to be for a shorter period in the pilots/demonstrations than in public programs. Three of the four projects in this category have ended. The Sacramento Envoy project, with GHGs and equity goals, is still ongoing but reduced its BEV feet by two-thirds (from 142 Electric vehicles to 48 electric vehicles). The scale of two of these projects (San Diego Car2GO and BlueIndy) was significant (300 electric vehicles and 282 electric vehicles, respectively). GHG reductions were the goal of both programs. The Chattanooga program included 20 electric vehicles and operated for three years with the goals of reducing GHGs and increasing transit access.

Private Ventures and Non-profit Demonstrations: The third category includes privately led public-private partnerships and non-profit demonstrations with a clear end date. Privately administered and sponsored, these projects may receive grant money and/or public space. However, outside of their grants and public space agreements, these programs are independent of public oversight. Two of the four projects included in this category have ceased operations (Portland's Hacienda and Los Angeles' Hyundai Mocean). The other two are currently operational (Sacramento's GIG and CRuSe in Hood River, Oregon). The Oregon programs are small (3–5 vehicles) pilots to test GHG and equity goals. Mocean included 100 electric vehicles and focused on increased accessibility. GIG operates 260 electric vehicles in a 13 square mile of central Sacramento. Its objectives are GHG reductions and improved accessibility.

Lesson Learned #6: There is a need for more evaluation of costs, benefits, and designs that incorporate lessons learned from evaluations.

Electric vehicle carsharing is a promising policy and infrastructure option to reduce vehicle travel and GHGs and improve equity of access. These services act as incentives for changing behavior, which is necessary where few alternatives to personal vehicles are available. Subsidized electric carsharing programs may provide an affordable alternative to high-quality transit that is costly to provide in rural and suburban areas. Pricing policies are very effective at inducing behavioral change. Still, they are likely to face extreme pushback from constituents who must travel long distances to access affordable housing and employment in suburban and rural areas. Electric carsharing may increase exposure to electric vehicles in rural areas, translating to acceptance and increasing the likelihood of electric vehicle purchases, at least among those who can afford them.

On the other hand, researchers know little about what these new wave projects will cost at scale and their actual benefits. It is critical to conduct peer-reviewed evaluations of these programs to verify and quantify the magnitude of benefits. Many of these programs use different business models and locate in different geographic contexts. Lessons learned from these programs should be documented over time as projects grow, evolve, and mature. Funding programs should reserve at least ten percent of project costs for research evaluation at this emergent stage. Evaluations need to move beyond usage data and integrate surveys (with reasonable response rates) and focus groups. This data is necessary to understand and document changes in travel behavior, GHG emissions, and access to opportunities for marginalized populations. Currently, ongoing funding mechanisms for these electric carsharing programs are uncertain. Peer-reviewed evaluations are necessary to justify the development of a funding mechanism to support these programs. Notably, CARB has increased its funding for evaluation, but more support is needed.

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Data Summary

Products of Research

This study collected data from publicly available resources that including carshare operator websites, media websites, press releases, academic papers, and public agency reports. This report also collected carshare operation metrics via questionnaires and confidential interviews with experts. These sources have been cited in the References section above.

Data Format and Content

Expert interviews were recorded for note-taking purposes and conducted under condition of confidentiality. The recording and responses to carshare metric questionnaire are not publicly available. Any quote included in this report that is attributed to an interview is utilized with the purpose of providing greater context to the collected quantitative and qualitative material.

Data Access and Sharing

The publicly available data sources are cited in the References section above. Recordings of expert interviews and responses to expert questionnaire are not publicly available.

Reuse and Redistribution

All cited publicly available documents are available to readers through conventional channels.