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Success factors for electric carsharing

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This briefing examines electric carsharing and the elements that are found in successful programs in North America and Europe. Specifically, it describes the benefits of electric carsharing, presents examples of carsharing, provides charging infrastructure insights, and identifies best practices for electric carsharing.

Introduction

Carsharing is the short-term use of vehicles from a designated parking station or distributed throughout a city in public parking spaces. Cars typically are accessed with a member card or smartphone without the need for human interaction, and users usually are charged by the time or distance driven, or a combination thereof.[1] This allows people to give up their cars while still maintaining the mobility that they previously had with car ownership. Carsharing also allows carless households better and more equitable access to goods and services that require a car to obtain.

Electric vehicles can be used for carsharing services when there is access to sufficient charging. Electric carsharing can enhance the environmental benefits of conventional combustion-engine carsharing and mitigate negative impacts. In 2019, a survey showed that 66% of all carsharing fleets were either all-electric or offered some electric vehicles, and 25% of countries with carsharing had cities where carsharing fleets consisted exclusively of battery electric vehicles. The five countries ranked the highest in terms of carsharing companies offering battery electric cars were Italy, the United States, the United Kingdom, Japan, and France.[2]

1 Elliot Martin and Susan Shaheen, "The Impacts of car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities," (Transportation Sustainability Research Center, University of California, Berkely, 2016), https://tsrc.berkeley.edu/publications/impacts-car2go-vehicle-ownership-modal-shift-vehicle-miles-traveled-and-greenhouse-gas.

2 Sandra Phillips, "Carsharing Market & Growth Analysis 2019," movmi (blog), July 10, 2019, https://movmi.net/blog/carsharing-market-growth-2019/.

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The reasons for the increase in electric carsharing are twofold. First, electric cars are becoming more attractive as they become less expensive, have increased electric range, and involve lower operating costs. Second, regulations are driving fleets to electrify. Greenhouse gas regulations in Europe in particular are spurring car manufacturers to put electric cars on the road at a rapid pace. Local regulations can also push fleets to electrify. In the United States, 16 of 24 cities in a 2018 survey had clear electrification policies for public and private cars in their city plan. Because city cooperation is generally needed for successful carsharing programs, cities have leverage with which to encourage electric carsharing.

There are different types of carsharing schemes. This report focuses on business-to-consumer carsharing, which includes roundtrip or one-way station-based service and one-way free-floating service. In this case, a station is a designated parking area for carsharing cars. This is not to be confused with a "charging station," which will be refered to as a "charger." Parking stations may not have charging. In roundtrip carsharing, the car is picked up and dropped off at the same station. For one-way station-based carsharing, the car is picked up and dropped off at established stations, and for one-way free-floating carsharing the car can be picked up and dropped off at any location within a zone. A combination of these models can also be undertaken.[3] Peer-to-peer carsharing, not covered in this report, allows private car owners to share their cars and is usually enabled through a third-party company that manages rental.

As of 2019, there were 236 carshare operators in 59 countries and 3,128 cities worldwide. The number of cities offering carsharing increased to more than 4,100 as of the beginning of 2021. Although free-floating carsharing is growing rapidly—its market share increased by 9% between 2017 and 2019—station-based models still dominate the market. The 2019 market share of the three main business models is presented in Figure 1.[4]

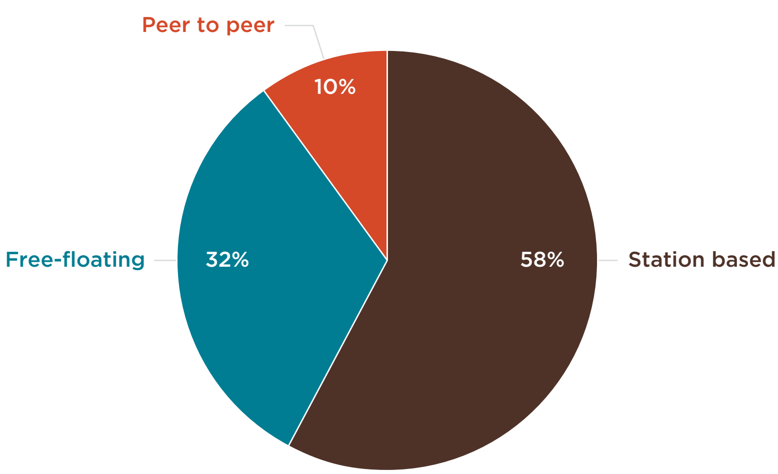

Figure 1. Percentage of carsharing operators by business model in 2019.

While the number of operators is greater for station-based carsharing, the fleet sizes in free-floating and peer-to-peer carsharing tend to be larger.

Three different zone and station combinations are shown in Figure 2. Parking stations are represented by shaded blue circles, chargers are represented by brown dots, and

3 Susan Shaheen et al., "Shared Mobility Policy Playbook," December 1, 2019, https://escholarship.org/uc/item/9678b4xs.

4 Phillips, "Carsharing Market & Growth Analysis 2019."

zones are indicated by shaded squares. In Figure 2A, one-way carsharing trips can start or end among any of the three stations while roundtrip carsharing requires the vehicle to start and end at the same station. Charging is typically available at every parking station. Figure 2B represents a free-floating zone in which one-way trips can start or end anywhere in the zone. All chargers are accessible to the public as well. Figure 2C is similar to Figure 2B but adds satellite parking stations and chargers outside of a zone which may serve as a trip beginning or end point. Finally, reserved parking and charging at a parking station can be incorporated within a free-floating zone, as shown in Figure 2D.

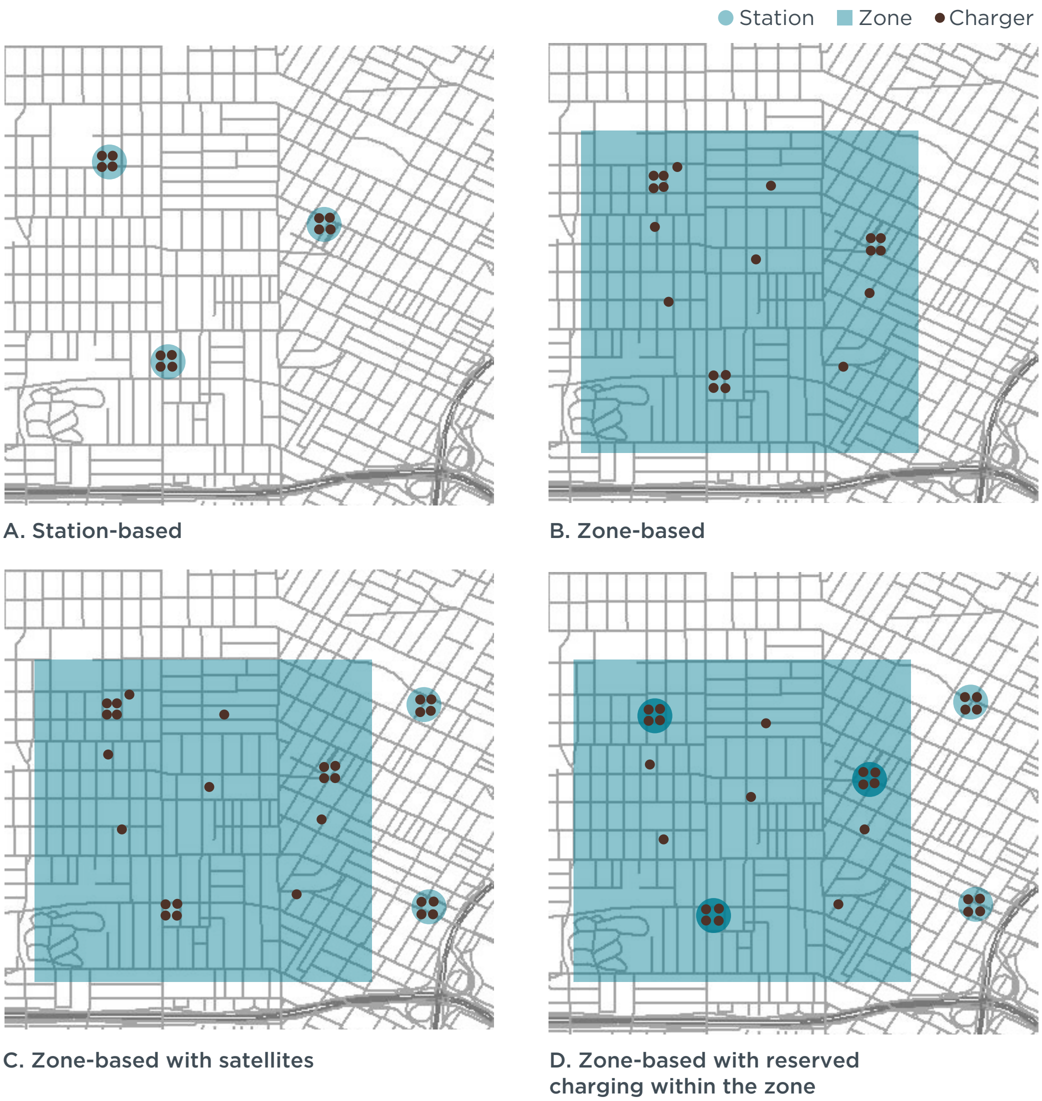

Figure 2. Zone, station, and charger arrangements that can be applied to one-way and roundtrip carsharing.

All of these station and zone arrangements have been applied to electric carsharing. The advantage of station-based carsharing is the easy integration of electric vehicle chargers, but the disadvantages are a lack of flexibility for users and available space at parking stations.

What are the benefits of electric carsharing?

Many studies have been conducted on the impact and the potential benefits of carsharing and most show that it has net beneficial social and environmental impacts.[5] When assessing the environmental impact, several factors are considered: change in car ownership, change in vehicle kilometers traveled (VKT), mode shift, and car efficiency.

Social impact

Studies show that carsharing has a range of beneficial social impacts by allowing a household to gain or maintain access to vehicles without bearing the cost of car ownership. Carsharing can give carless households equal access to jobs, goods, and services. Not only do shared electric vehicles have no tailpipe emissions, which benefits air quality, but they also increase zero-emission vehicle exposure, allowing more people to become familiar with this new technology, and can thus lead to increased electric vehicle market share.[6] Additionally, if pollution is higher, as is the case in many low-income areas, electric vehicles help reduce air pollution.

Environmental Benefits

Carsharing lowers VKT from private automobiles in most studies, consequently lowering emissions and reducing traffic. Electric vehicles amplify these emission benefits. In some studies, roundtrip carsharing reduces more VKT per user and is slightly better in terms of cars removed from the roads than one-way carsharing. Roundtrip carsharing serves the same function as a personal car since it is picked up and dropped off at the same place in one's own neighborhood and thus might be a more convincing replacement for a personal car. Additionally, roundtrip carsharing subscribers increased their public transit usage while one-way carsharing users slightly decreased it. However, because free-floating schemes allow more flexibility and have larger fleets, they have the potential to attract more customers, which in some cases could increase the comparative environmental and social impacts over roundtrip carsharing.

For densely populated cities, the greatest promise of any carsharing program may be the decrease in the number of private vehicles parking on city streets. The resulting increase in available space is valuable for a multitude of purposes including increasing economic activity due to easier parking, redesignating space for alternative modes such as bikeshare and other micromobility options, or recapturing space for outdoor cafes and pedestrians. However, this potential to increase parking availability is not immediate. If a large fleet of carsharing vehicles is deployed quickly, there will be a net decrease in available parking in the near term. Users must have time to trust the availability of cars and to prompt a vehicle sale or delay the purchase of a new one.

Table 1 summarizes the environmental benefits associated with both roundtrip and one-way carsharing in three studies. The benefits are in terms of decreased car ownership, a decrease in VKT, mode shifting, and a reduction in transportation-related greenhouse gases (GHG). The decreased car ownership category has two different metrics depending on the study. It can be expressed in terms of the number of cars replaced per

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5 Shaheen, Susan, Adam Cohen, and Emily Farrar. (2019). Carsharing's impact and future. In E. Fishman (Ed.), *Advances in Transport Policy and Planning* (pp. 87–120). https://doi.org/10.1016/bs.atpp.2019.09.002.

6 Shaheen, Susan, Elliot Martin, and Hannah Totte. (2020). Zero-emission vehicle exposure within U.S. carsharing fleets and impacts on sentiment toward electric-drive vehicles. *Transport Policy*, 85, A23–32. https://doi.org/10.1016/j.tranpol.2019.09.008.

carsharing car or as a car ownership decrease, which is a simple percentage decrease in cars among users.

Table 1. Summary of environmental benefits associated with carsharing.

Source	Location	Decreased car ownership				VKT decrease	Mode shift		GHG reduction per customer
		One way		Roundtrip			One-way	Roundtrip	
		Number of cars replaced	Car ownership decrease	Number of cars replaced	Car ownership decrease		Public transit usage		
car2go[a]	North America	7 to 11	—	6 to 23	—	6% to 16%[b]	3% to 8% reported an increase and 21% to 48% reported a decrease	4% to 54% reported an increase and 2% to 13% reported a decrease	-4% to 18%
car2go and DriveNow[c]	Europe	7 to 18	—	3 to 10	—	3% to 36% (conservative scenario), 10% to 92% (optimistic scenario)	—	—	-9% to -43% (highest reduction in Copenhagen with EV carsharing and a clean electricity grid)
Autolib' (one way) and Mobizen (roundtrip)[d]	Paris	3	23%	7	67%	—	-18%	2% to 14%	—

[a] Martin and Shaheen, "The Impacts of car2go on Vehicle Ownership."

[b] These percentages include the "empty kilometers" driven by employees to redistribute and/or charge cars. The share of kilometers driven for this purpose ranged from 3% to 7.5% for conventional vehicles and up to 17% for early low-range electric vehicles that required frequent attention to ensure the batteries were sufficiently charged and redistributed around town.

[c] Fromm, Hansjörg, Lukas Ewald, Dominik Frankenhauser, Axel Ensslen, and Patrick Jochem. (2019). "A Study on Free-Floating Carsharing in Europe: Impacts of car2go and DriveNow on Modal Shift, Vehicle Ownership, Vehicle Kilometers Traveled, and CO2 Emissions in 11 European Cities." Working Paper Series in Production and Energy. Karlsruhe Institute of Technology (KIT), Institute for Industrial Production (IIP). https://ideas.repec.org/p/zbw/kitiip/36.html

[d] 6t and ADEME, "L'autopartage en trace directe: quelle alternative à la voiture particulière? [Direct-track carsharing: what alternative to the private car?]" Retrieved from https://www.ademe.fr/sites/default/files/assets/documents/autopartage-en-trace-directe-quelle-alternative-voiture-particuliere-8167.pdf

Most studies suggest that one shared car can eventually replace about 10 private vehicles parked on city streets. All studies found a decrease in GHG emissions as a result of carsharing, with the largest decrease from a partially-electrified carsharing program in Copenhagen. Mode shift is less clear; although more people reported a decrease in transit use in one-way carsharing, there is no overall magnitude reported. For those who gave up their cars, the increase in transit use is much higher, which may counteract the slight decrease in usage from those relying only on transit before carsharing.

Electric carsharing program examples

Electric carsharing has the potential to increase the environmental benefits of a carsharing fleet and, therefore, has been encouraged by policy makers. However, electric carsharing pilots and programs have met with mixed success. Integrating electric vehicle charging and managing shorter driving range adds a layer of complexity to carsharing in general. This section reviews past and current electric carsharing schemes, with a particular focus on charging infrastructure.

Electric carsharing programs have been experimented with for more than 20 years with the first large scale demonstrations beginning in the 1990s in France.[7] Yelomobile began

7 Shaheen, Susan, and Nelson Chan. (2015). Evolution of e-mobility in carsharing business models. In D. Beeton and G. Meyer (eds) *Electric Vehicle Business Models* [Lecture Notes in Mobility series]. Springer, Cham. https://doi.org/10.1007/978-3-319-12244-1_10.

in 1993 as a station-based roundtrip service in La Rochelle and is still operating today with government support as a station-based one-way carsharing service. Low-range electric vehicles that could complete short trips were seen in the 1990s as a good match for carsharing, provided they return to a charger. More than 10 different pilot projects were tested in the 1990s and early 2000s in the United States, Europe, and Asia, but by 2006 most electric vehicles in carsharing fleets had been displaced by hybrid-electric vehicles. Although users found electric cars largely adequate, high costs, high insurance rates, increased vehicle downtime, and low reliability were cited as reasons for the failure of various programs.

Even though electric carsharing adds logistical challenges to a carsharing scheme, it has seen renewed interest in the past 10 years after early failures. Modern electric vehicles have greater range, require less maintenance, and have lower energy costs, which results in a lower total cost of ownership (TCO) compared to internal combustion engines. Although the upfront cost is still higher, cost parity with comparable conventional cars should happen in the next five to 10 years.[8] Additionally, the higher upfront costs are spread among many drivers, improving TCO.

We examine 17 different electric carsharing programs, presented in Table 2, to extract lessons on how they have been implemented. Three types of carsharing programs are shown: one-way station-based, one-way free-floating, and roundtrip. For programs that are no longer operating, we show fleet sizes at the peak of operation and the corresponding infrastructure. Otherwise, the fleet and charging infrastructure as of early 2021 is shown. In the last column on the right, the average number of public chargers per square kilometer is shown for programs that operate in zones. Clem' a station-based operator, also shares its chargers with the public but must still ensure that there are enough chargers for its own operation. Vehicle ranges vary between 160 kilometers (km) or less in the early programs to a maximum of 400 km in the newest programs.

8 Lutsey, Nic, and Michael Nicholas. (2019). *Update on Electric Vehicle Costs in the United States through 2030*. Retrieved from the International Council on Clean Transportation, https://www.theicct.org/publications/update-US-2030-electric-vehicle-cost.

Table 2. Electric carsharing program examples.

Electric carsharing program	Type	Initiative	Location of the case study	Dates of operation	Size		
					Fleet	Charging infrastructure	Chargers per square km in central zone
Autolib'	One-way station-based	Public initiative	Ile de France (mostly Paris)	2011–2018	4,000 BEVs	6,000 private chargers	
BlueLA	One-way station-based	Public initiative	Los Angeles	2017–present	100 BEVs	200 private chargers	
BlueLy	One-way station-based	Private initiative	Lyon	2013–2020	227 BEVs	514 private chargers and 100 stations	
BlueCub	One-way station-based	Private initiative	Bordeaux	2014–2020	147 BEVs	74 stations and 354 private chargers	
car2go	Free-floating	OEM – Daimler	San Diego	2011–2016		All EVs charged by staff members at a depot	
WeShare	Free-floating	OEM – Volkswagen	Berlin	2019– present	1,600 EVs	140 chargers at grocery stores after hours + 1,020 public chargers	6.7
WeShare	Free-floating	OEM – Volkswagen	Hamburg	2021 (estimated)– present	800 EVs	790 public chargers	7.8
DriveNow	Free- floating	OEM – BMW	Copenhagen	2015–2018	400 EVs	—	—
ShareNow	Free-floating	OEM – BMW & Daimler	Copenhagen	2018–present	650 EVs	740 public chargers	9.7
ShareNow	Free-floating	OEM – BMW & Daimler	Munich	2018–present	200 EVs	1000 public chargers	7.8
GreenMobility	Free-floating and station-based.	OEM – Renault	Copenhagen	2016–present	450 EVs	740 public + 60 station chargers (estimated)	10.5
Zity	Free-floating and station-based	OEM – Renault	Madrid (94km^2 free-floating zone)	2016–now	800 BEVs	Depot charging. Only staff members are allowed to charge the BEVs.	
E-Vai	One-way station-based	Company of the Northern Italy Railway group	Lombardy (Milan region) Urban and rural	2011–now	320 EVs (mainly BEVs)	130 E-Vai stations in Lombardy, among which 70 have charging stations.	
ZipCar	Free-floating	Partnership with Volkswagen for electric vehicles	London	2018–now	325 BEVs (goal of 9,000 in 2025)	Recharged overnight at rapid charge points across the capital by staff members.	
Maven	Free-floating	OEM - General Motors	USA	2015–2020	unknown	Partnership with EVgo, exclusively charging at DC fast stations both public and private.	—
GIG car share	Free-floating	Private initiative sponsored by AAA	Sacramento (13mi^2 free-floating zone)	2019–now	260 BEVs	Charging at public Electrify America chargers	—
Clem'	Roundtrip	Public initiative	Mostly rural French areas	2010–now	400 BEVs	600 quasi-public chargers	
Nissan e-share mobi	Roundtrip	OEM - Nissan	Japan	2018–now	230 EVs (BEVs and range extended EVs)	230 stations in 20 cities (76 in Tokyo)	

The table above suggests more chargers are needed than cars for one-way and roundtrip station-based carsharing. However, in free-floating carsharing, where charging is likely to be done at public chargers, a coverage metric may be more relevant. A public network of around seven chargers per square kilometer is regarded as sufficient coverage to support convenient carsharing, with 10 being preferable.[9] For the size of the Berlin zone, seven chargers per square kilometer suggests that Berlin would ideally contain at least 1,220 chargers to achieve sufficient coverage for its vehicles.

A unique issue with electric carsharing is managing battery charge level. Related to this, interesting insights can be drawn from the car2go San Diego experiment. Car2go San Diego—a free-floating electric carsharing scheme from the automaker Daimler—decided to operate a centralized charging depot to charge its vehicles due to insufficient public charging availability. When battery level dropped under a certain level, a staff member would drive the car to the depot to charge it and then drive it back to the service. Of all miles driven in the program, 17% were driven by staff members. This program ran from 2011 to 2016 with electric cars with only 58 miles of range; BEV range has improved since then, suggesting that less frequent charging is possible in more recent programs.

In addition to the challenge of maintaining sufficient charge in EVs, car2go had to prevent the accumulation of vehicles in low-demand areas. To deal with these two issues, car2go tested different pricing and user incentives.[10] The first was designed to encourage people to drop off their car close to the charging depot to reduce staff miles; the second was designed to manage supply and demand by moving vehicles away from regions of heavy car accumulation. Both incentives gave users 10 free minutes, equal to a $12 credit, which proved effective in changing driver behavior.

Autolib', managed by a group of municipalities, was an ambitious partnership between Métropole du Grand Paris and Bolloré for a one-way station-based carsharing program with 4,000 cars and 6,000 chargers. Autolib' struggled to maintain a sufficient and well distributed fleet. Although the number of subscribers increased, it became difficult for customers to find available vehicles. Facing several failed attempts at finding a car, some customers stopped using Autolib' despite the company increasing the number of vehicles in its fleet. As a result, the carsharing program failed. Some studies draw the conclusion that there might be an optimized number of customers per car. For Autolib' it would have been around 24 users per vehicle.[11]

Interestingly, all electric station-based schemes investigated that are still operating are the result of public tenders or demand, as opposed to private initiatives, and benefit from public funding whereas most of the electric free-floating ones do not. However, many of the successful free-floating schemes benefit from public support in the form of parking policies, community outreach, or accessibility benefits.

9 Carl Friedrich Eckhardt (personal communication, February 10, 2021)

10 Shaheen, S. (2018). *One-way Electric Vehicle Carsharing in San Diego: An Exploration of Behavioral Impacts and the Impact of Pricing Incentives on Improving Operational Efficiency* (Report CA18-2499). Retrieved from https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/f0017091-ca18-2499-finalreport.pdf

11 Lagadic, Marion, Alia Verloes, and Nicolas Louvet. (2019). Can carsharing services be profitable? A critical review of established and developing business models. *Transport Policy 77*, 68–78. https://doi.org/10.1016/j.tranpol.2019.02.006.

City strategies

This section reviews city policies regarding electric carsharing in order to meet city goals. As carsharing schemes depend on city coordination, a review of different approaches to managing carsharing is useful for cities as they formulate their own carsharing policies.

Copenhagen

Copenhagen, Denmark, developed a strategy in 2017 to enhance carsharing in the city.[12] This strategy focused only on roundtrip carsharing because the city council determined that research has only been able to demonstrate the impact of roundtrip schemes, and not of free-floating schemes, on congestion and car ownership. This strategy laid out 15 initiatives and requirements: a tripling of the shared fleet from 250 vehicles in 2017, a requirement for at least 30% electric shared cars by 2020, the goal of integrating carsharing with public transport and city bikes, a plan to work on community outreach and communication, and parking benefits to roundtrip schemes. To enhance integration with public transportation, the city council implemented carsharing parking hubs close to public transit and bike stations. Copenhagen also offered a discount on carsharing membership to municipal employees.

Paris

Paris has different strategies and regulations in place for free-floating and roundtrip carsharing. Its free-floating fleet is already 100% battery electric and, since January 2021, free-floating operators face new regulations including data sharing, mandatory annual carbon reporting, maintenance requirements, and even fleet distribution within the city.13 Free-floating operators pay different fees to the municipality depending on their fleet size and on the size of their vehicles. For roundtrip fleets, 65% are electric (31% BEV and 34% PHEV). Because the public charging network is not dense enough in the surrounding areas where customers drive these shared roundtrip cars, Paris does not currently have 100% electric roundtrip fleet requirements. Putting in place such requirements could be counterproductive and deter households from giving up their cars to rely on shared mobility. Finally, agreements between Paris and the roundtrip operators were recently extended to 5 years for internal combustion engine operators and 7 years for electric vehicles operators. The agreements last longer for EV operators to allow more time for return on investment because developing an electric roundtrip carsharing scheme is more capital intensive.

Madrid

Since June 2020, Madrid, Spain, has implemented zones exclusively reserved for carsharing parking.[14] Carsharing cars can also park on city streets with free-floating programs. The city council decided to implement these parking zones because, with more than 82% of the shared fleet consisting of zero emission vehicles, it considers carsharing a sustainable transportation mode. This important share of electric vehicles in

12 Københavns Kommune. Strategi for delebiler i København [Strategy for car sharing in Copenhagen]. Accessed February 26, 2021. https://www.kk.dk/artikel/strategi-delebiler-i-koebenhavn.

13 Bulletin official de la ville de Paris. (January 29, 2021). Règlement relatif à la délivrance des titres d'occupation aux opérateurs de véhicules partagés en libre-service sans station d'attache [Regulations relating to the issuance of occupation titles to operators of shared self-service vehicles without docking station]. Retrieved from https://cdn.paris.fr/paris/2021/01/29/fdccee8e0e9fa4f9fd3a76bf3fa35f8c.pdf

14 Autocasión. (June 8, 2020). Primer parking exclusivo para coches compartidos en Madrid [First exclusive parking for shared cars in Madrid]. Accessed February 26, 2021. https://www.autocasion.com/actualidad/noticias/aparcamiento-parking-exclusivo-carsharing-coche-compartido-madrid.

the fleet is partially the result of the city's decision to allow all electric vehicles to enter the Restricted Access Zone for free and grant free parking in many locations.

Milan

The city of Milan, Italy, is committed to promoting shared mobility to enhance transportation sustainability and increase public space quality by removing parking places.[15] The city applies a range of measures to promote vehicle sharing, including discounted carshare parking permits and a flat fee for parking privileges in the congestion zone. Furthermore, the city is developing mobility hubs where all forms of shared mobility are co-located, as well as a mobility-as-a-service program, which includes a single app to get information and access to all mobility services operating in the city. Milan has a clear objective of moving all shared mobility services toward zero emissions. Each carsharing company pays a concession fee to Palazzo Marino, which is higher for companies operating internal combustion engine (ICE) vehicles and is set to increase for non-all-electric operators in coming years. In addition, ICEs will be banned from carsharing schemes in 2024, following a decision from Milan Municipal Council. Electric shared vehicles do not have to pay parking fees in the congestion zone until 2023.

Ghent

Ghent, Belgium, has adopted a CarShare Action Plan containing measures to increase carsharing.16 Shared cars can enjoy free parking in Ghent and have reserved parking places, including special permits for the city's restricted access zone. Some of these reserved spaces are clustered around public transport and combined with other shared mobility services such as bikes and scooters. Furthermore, there are subsidies for carsharing memberships and for the purchase of electric shared cars that become part of the carsharing fleet. The city stated the goal of 50% electric vehicles in the shared fleet by 2024.[17] The city administration also uses shared vehicles for work-related travel whenever possible.

Charging infrastructure analysis

The chargers-per-vehicle metric demonstrates the difference in charging infrastructure requirements among the carsharing business models. Figure 3 displays the number of cars per charger for different schemes and cities. The top four programs in Figure 3 are one-way station-based and the stations are exclusively for the company's carsharing customers. The next three are one-way free-floating and rely on public charging. The free-floating zones were mapped and normal speed (<22 kilowatt) chargers inside the zone were totaled. And finally, the roundtrip operator Clem' has parking stations with extra chargers so that there are enough for public use as well.

15 Gobbi, D. W. (November 5, 2019). Milano carsharing: solo elettrico dal 2024 [Milan car sharing: only electric from 2024]. Retrieved from https://www.clubalfa.it/76529-milano-car-sharing-solo-elettrico-dal-2024.

16 Autodelen Gent. (n.d.) Autodeelplan Gent (Ghent car sharing plan). Accessed February 26, 2021. https://autodelen.gent/vibe/vibe-4/.

17 CoMoUK. (2021). *Shared mobility and a car-free centre in Ghent*. Retrieved from https://como.org.uk/wp-content/uploads/2021/01/CoMoUK_Mobility-Hubs_Ghent-Case-Study-A4.pdf

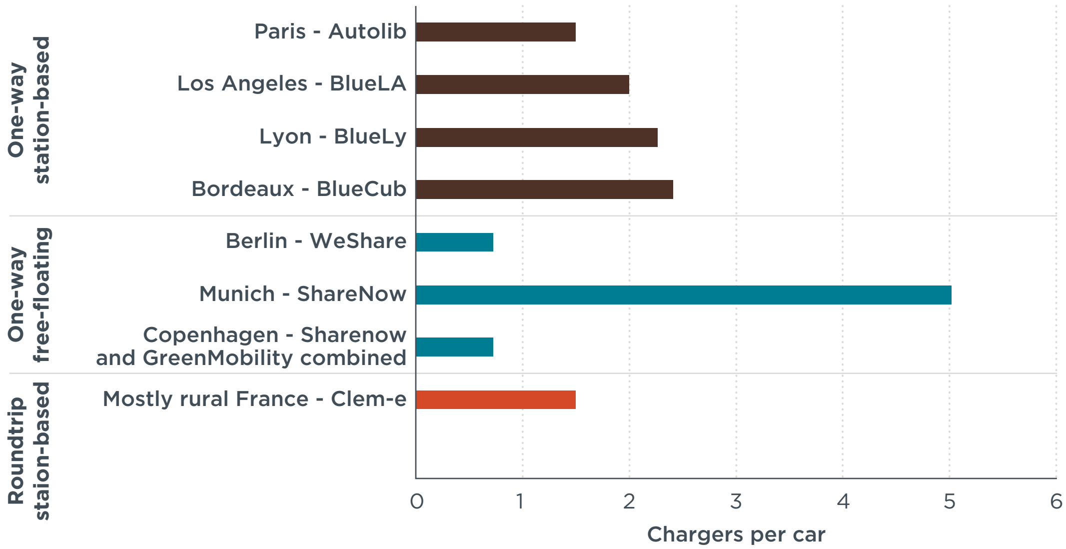

Figure 3. Chargers available per carsharing car in different cities.

In general, station-based one-way carsharing requires more than one charger per vehicle to ensure that each parked car is plugged in and charged for the next trip. The three cites displayed that use public chargers for carsharing—Berlin, Munich, and Copenhagen—show that it is possible to have less than one charger per car and the public is able to use the chargers as well. In the case of Munich, the electric carsharing fleet is small, suggesting that more carsharing cars could be supported. However, any expansion of a carsharing fleet should first investigate whether private cars are causing charging congestion apart from any carsharing use.

To determine the impact of carsharing on the public charging system, we look at the number of kilometers a carsharing car completes per year as calculated from various studies.[18] In Berlin, a carsharing car traveled about 16,000 km per year and in Copenhagen, a carsharing car traveled about 8,000 km. For scenario purposes, we choose the value of 15,000 km per year. Table 3 shows further assumptions used to arrive at the number of hours per day per charger a carsharing car uses the public network.

18 Fromm, Hansjörg, Lukas Ewald, Dominik Frankenhauser, Axel Ensslen, and Patrick Jochem. (2019). "A Study on Free-Floating Carsharing in Europe: Impacts of car2go and DriveNow on Modal Shift, Vehicle Ownership, Vehicle Kilometers Traveled, and CO2 Emissions in 11 European Cities." Working Paper Series in Production and Energy. Karlsruhe Institute of Technology (KIT), Institute for Industrial Production (IIP). https://ideas.repec.org/p/zbw/kitiip/36.html.

Table 3. Assumptions used to determine charger usage per day of free-floating carsharing cars

Travel per carsharing car (km/year)	15,000
Efficiency (km/kilowatt-hour)	5.3
Consumption (kilowatt-hour/day)	7.8
Charger power (kilowatts)	Europe 10, United States 6.6
Hours charging per day per car	Europe 0.8, United States 1.2
Chargers recommended per square km in free-floating programs	7
Cars recommended per square km in free-floating programs[19]	7

Using the assumptions in Table 3, we see that to support a carsharing car, 0.8 hours or 48 minutes of charging per day on average are required in Europe, and 1.2 hours or 1 hour 12 minutes in the United States.

Using the required charging times shown in Table 3, we construct charging scenarios to support carsharing fleets of different sizes in the United States and Europe in Figure 4. The one-way station-based programs are assigned 1.5 chargers per carsharing car based on the past programs shown in Figure 3, and roundtrip carsharing is assigned only one charger per car because each roundtrip car will return to its original location and potentially the same parking spot. One-way free-floating carsharing requires more parameters to make an estimation. The size of the free-floating zone determines the minimum chargers necessary at seven chargers per square km. The free-floating zone size chosen for scenarios is a 100 square km zone, similar in size to many of today's zones. A threshold of 2 hours of carsharing usage per day on public chargers is chosen so that there is also ample public access for charging. This translates to 0.4 and 0.6 public chargers needed per carsharing car in Europe and the United States, respectively.

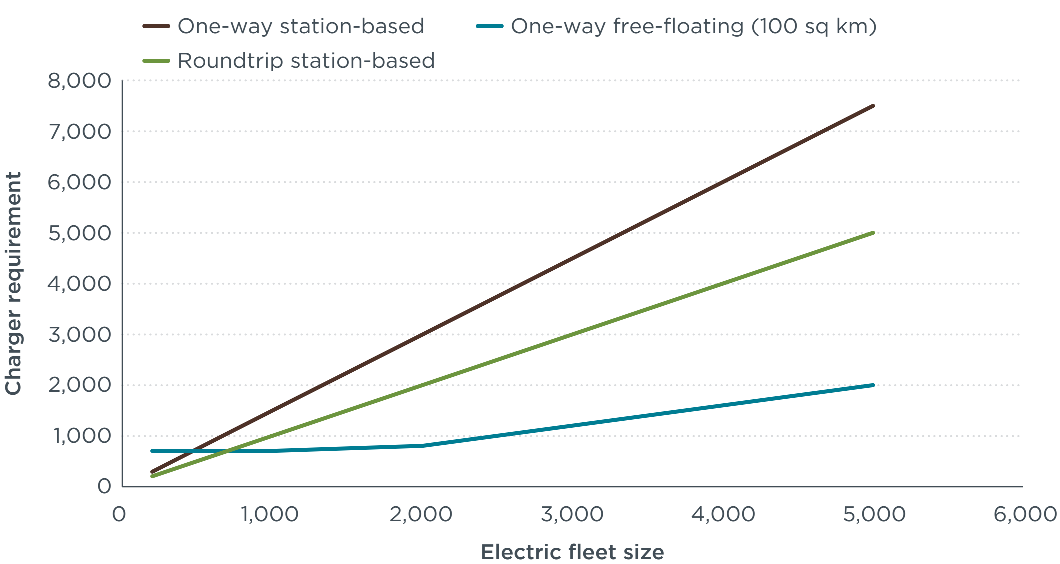

Figure 4. Chargers required based on fleet size, by business model.

19 Vulog, "7 Key Ingredients for Carsharing Success," n.d., https://info.vulog.com/7-key-ingredients-for-carsharing-success-new-edition.

Station-based carsharing requires more charging infrastructure than free-floating, except when a program is small. For a small, 200 electric vehicle fleet, the charger requirement is still seven chargers per square km. For a free-floating zone of 100 km square, at least 700 chargers are needed. Additionally, because 200 cars in a 100 km square zone cannot satisfy the seven cars per square km threshold, this implies that the electric fleet would have to be supplemented with 500 conventional cars to be a viable free-floating program from a user perspective. When the size of the fleet is 2,000 or more cars, charger capacity rather than coverage is the limiting factor and the ratio of 0.4 and 0.6 public chargers per carsharing car determines the necessary infrastructure. This also assumes that public charger installation proceeds at historical rates leaving at least 2 hours available for charging by carsharing services.

Free-floating carsharing works best when there are at least seven cars per square km and seven chargers per square km to increase the likelihood that a car is within a five-minute walk. For smaller programs or rural programs, station-based is the best way to manage an electric carsharing fleet. As public charging becomes more available, cities are more likely to have a charging infrastructure able to support a carsharing fleet. Finally, charging should cover the entire zone to ensure uniform availability and usage data should inform where to add more charger capacity in popular areas.

The role of DC fast charging is unknown, as customers generally go point to point without any idle time. Incorporation of fast charging would likely require reimbursement for the time spent charging in terms of a monetary incentive or a time credit able to be applied to future carsharing use. In the case where the time between rentals is short, fast charging could allow higher turnover and allow one customer to drop off the car and another to pick it up without leaving a car charging on a fast charger for an unnecessarily long time.

Best practices to encourage electric carsharing

This section summarizes best practices for cities to encourage electric carsharing in a way that fits their goals and priorities. In almost all cases, governments can determine the success or failure of an electric carsharing program. It is therefore essential for governments to be active partners for successful carsharing to ensure that they meet their goals for parking relief, decreased car dependency, VKT reduction, traffic reduction, GHG reduction, and social equity. Although carsharing is an important tool for achieving these goals, carsharing by itself cannot confer all these benefits. Discouraging private car use and associated effects amplifies the effectiveness of carsharing to achieve desired goals.

Governments can develop strategies, such as those illustrated in the preceding city strategies section, and their support can take many different forms ranging from coordinating multimodal integration and customer outreach to providing financial incentives such as zero emission mandates and direct subsidies. Governments can provide parking benefits and charging infrastructure access or installation coordination. Many best practices for electric carsharing are common with conventional carsharing and will also be mentioned here.

The importance of the business model

When cities are partnering with carsharing services, encouraging the right business model is crucial. There is no one business model that fits all; rather, the best model depends on the population density of the area and the goals of both the local municipality and the operator. This section compares a mix of three different business models: one-way free-floating, one-way station-based, and roundtrip station-based.

Some general rules of thumb can help determine which business model may be successful in a city and whether a free-floating scheme is a good choice.[20] Free-floating schemes have been successful in cities of 500,000 people or more and at least 1,500 people per square km. Station-based carsharing can also be appropriate in the same dense cities, but offerings can be tailored to different groups. Station-based carsharing can be successful in cities with less than 100,000 people. Figure 5 applies these population, density, and charger availability thresholds to determine which electric carsharing models are likely to be most appropriate for a city to pursue with carsharing partners. The flowchart starts with the gray box detailing the overall purpose of carsharing. The blue boxes are process steps and the green boxes suggest the best business model based on the process steps.

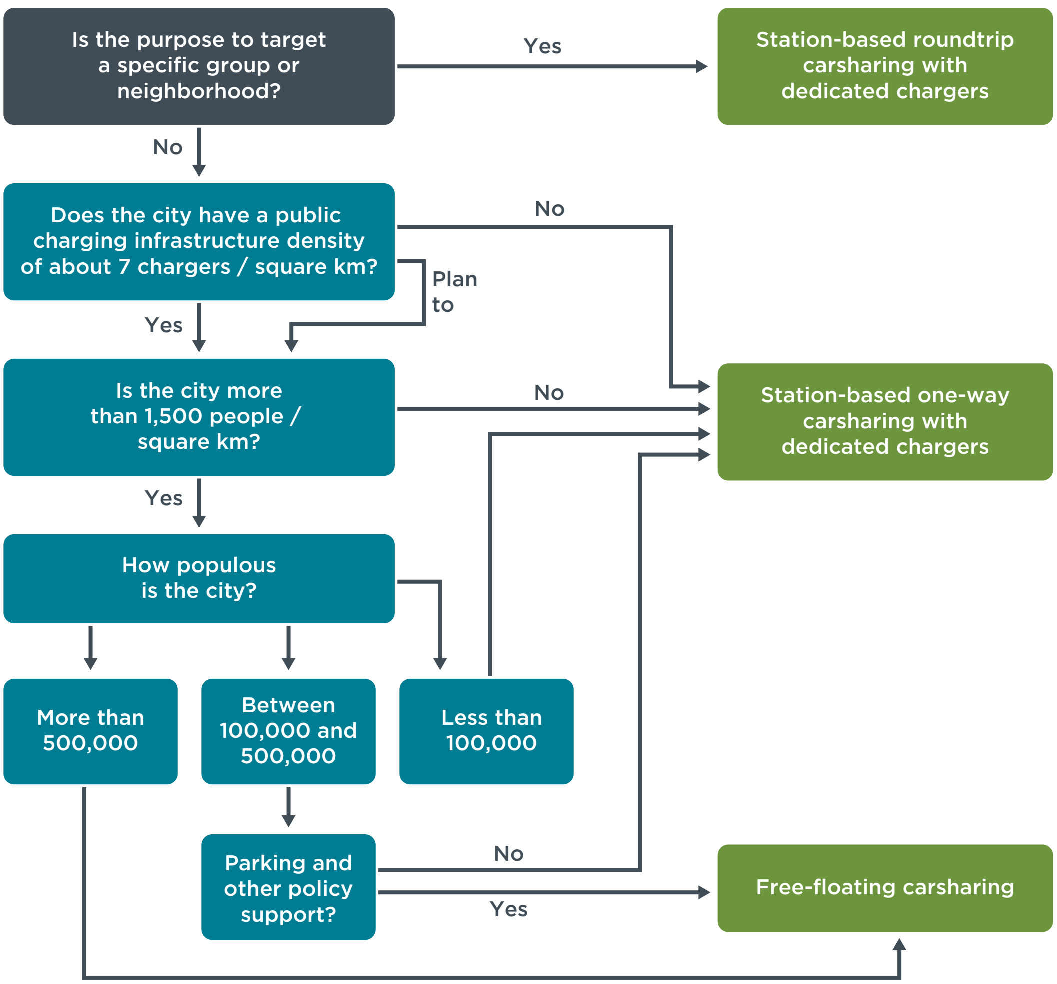

Figure 5. Flow chart to determine which business models are likely to be successful based on existing city conditions and city goals.

The figure only roughly guides which business models will be successful and desirable, and more than one business model can exist in a city. For example, a roundtrip

20 "Understanding the Carsharing Business Model and How to Build Yours," movmi (blog), February 8, 2018, https://movmi.net/blog/car-sharing-business-model/.

station-based model can be successful in a large, densely populated city alongside a free-floating model if there is a need for a tailored service such as targeting a low-income neighborhood or integration with transit hubs. A station-based one-way carsharing model may be preferred in a large city to target specific groups with limited destinations. Alternatively, free-floating carsharing partners can be required to abide by certain rules and contracted to serve certain fleets or groups in lieu of a station-based system to accomplish city goals.

Zone and fleet size are also considerations in determining if a free-floating carsharing program is right for a city. Free-floating carsharing has been successful when the density of cars (as well as chargers) within a free-floating zone is at least seven per square km. Initially, this will result in a loss of seven parking spaces per square km, but parking place loss may be unequally distributed. Rules of thumb suggest a minimum fleet of 250 cars, which can grow to 1,250 cars or more. This suggests that a city will, at first, lose at least 250 parking places and have a minimum zone size of 36 square km. Studies suggest that, over time, each carsharing car will replace 10 private cars, so the 250 parking space loss will be counteracted by a gain of 2,500 parking spaces or a net gain of 2,250 parking spaces, but these transitions take time. One strategy to minimize short-term parking loss is to start with a smaller fleet and require that the carsharing operator prove that there is a net gain in parking space before adding more cars.

In less densely populated and even rural areas, the purpose of promoting carsharing may shift from primarily reducing parking pressure, VKT, GHG, and traffic to providing equitable mobility options for those who do not currently have or cannot afford a car. Since the viability of free-floating carsharing within a zone decreases with less population density, station-based roundtrip car-sharing can become the most viable option. Roundtrip carsharing also offers the advantage of guaranteeing a parking spot, which can be a large consumer benefit in cities.

In a less densely populated city, the usage of vehicles will drop proportionally with an operator less able to recoup costs unless there is government support. In lower density cities with populations between 100,000 and 500,000, station-based fleets with fewer cars and fewer chargers may be the best choice. Although one-way and roundtrip station-based operations may be easier to establish for smaller fleets with fewer chargers, they restrict the locations people can end a trip. However, station-based schemes can target user groups who are a priority for a city.

There is a trade-off among fleet size, charging infrastructure, and staff size. It might be more efficient to have a larger fleet and more charging infrastructure to decrease the distance driven by staff members, as opposed to users, for car relocation and charging.

From an operator experience perspective, better car utilization can be achieved when offering both business-to-consumer and business-to-business services. Indeed, although business vehicles might be used mostly during weekday mornings and evenings, offering the cars to private users on weekends and holidays is possible. E-Vai in Italy offers electric carsharing to a combination of private individuals, businesses, and public administrations. Through its “Easy Station” concept, commuters leave the vehicles at public transit stations, and companies adjacent to the station use the vehicles during the day for work activities. Commuters then take the cars back home in the evenings and also use them over the weekends.[21]

21 E-vai. n.d. “Il tuo carsharing elettrico regionale (Your regional carsharing).” Accessed March 10, 2021. https://www.e-vai.com/.

Clem', the French electric carsharing leader in rural areas, works with private individuals, municipalities, and businesses. Its novel business model—operating either its own vehicles or cars owned by its customers and operating a charging infrastructure network—and its partnerships with local authorities are key factors in Clem's carsharing success. Indeed, Clem's ability to tailor its offer to its customers' needs is often cited as one of the main reasons for support by municipalities.[22]

Charging infrastructure

For one-way free-floating carsharing, providing flexibility in charging options appears to be the best strategy. Establishing a robust public charging network in city parking lots and on curbsides with access for carsharing vehicles, or allowing a carsharing company to establish those chargers, can lead to viable one-way free-floating carsharing. For markets with little public charging, a preliminary charging infrastructure network is needed. Cities can partner with carsharing operators to establish chargers in locations that are convenient for carsharing customers. Free-floating carsharing typically has no fixed parking stations and all charging is done either at public chargers or privately by the operator's staff members.23 However, fixed stations inside a zone with multiple chargers, and an incentive for customers to plug-in at the end of their trip, can aid in the free-floating model. This has proven successful in Copenhagen, where GreenMobility incorporates "hotspots" within the free-floating zone with chargers in this manner.

Carsharing companies can also help to establish charging stations available to the public. Clem' partnered with cities to allowing both private electric car owners and Clem' carshare users to book a charger in advance. This provides the triple benefit of optimizing public space and resource usage, expanding the city's public charging network, and generating additional revenue. Clem' also ensures interoperability of its system and updates its system as technology changes. For example, the company optimizes charging to minimize the carbon intensity of the electricity and the impact on the grid through smart charging. However, making stations available to the public can come with additional expense and complexity, and there may be a need for additional discussions between cities' regulatory bodies and carsharing operators if such a model is envisaged.

Chargers tailored to carsharing can also become stranded assets if a carsharing scheme fails. This happened in Indianapolis with the one-way, station-based BlueIndy carsharing venture, which stopped operation in 2019. The city and local utility contributed $7 million to create special parking spaces with chargers reserved only for BlueIndy cars. The spaces are currently not an efficient use of space and the chargers are not up to current industry standards, providing less power than most other level 2 chargers in the market. One of the main reasons stated for this carsharing scheme failure is high car ownership and Indianapolis private car culture leaving little room for carsharing activity. [24] The city and utility did not see any recovery of investment. Creating charging that could be easily used by the public in the event that the business failed could have hedged against this possibility.

22 Clem'. n.d. "Drive towards ecomobility!" Accessed February 26, 2021. https://www.clem-e.com/?lang=en.

23 Share Now. n.d. "Fueling & Charging." Accessed February 26, 2021. https://www.share-now.com/de/en/faq/fueling-and-charging/.

24 Pak-Harvey, Ameila. (2020, September 24). Indianapolis will not buy BlueIndy charging stations. *IndyStar*. Accessed March 24, 2021. https://eu.indystar.com/story/news/local/indianapolis/2020/09/21/blueindy-indianapolis-not-buy-charging-stations/5851409002/.

Another business model is to allow carsharing vehicle owners to charge while the chargers are not needed for businesses. As an example, WeShare cars in Berlin can be charged at an additional 140 charging points at Kaufland and Lidl grocery stores outside of business hours thanks to a partnership between Volkswagen and these stores.

Parking policies

Access to parking is key for any carsharing model. Because each carsharing car has the potential to eventually remove roughly 10 private cars from a city, there is a net positive effect on the availability of parking. In dense cities, if carsharing cars pay the same parking rate as private cars, the business case is still strong. However, if private cars pay less for parking than carsharing cars, private car owners will be more likely to keep their cars and carsharing will be at a disadvantage. This is the case in Berlin where the yearly cost to park a private car is about €10 and carsharing cars must pay €6 per day.[25]

Preferential parking rates offered to the carsharing company or even free parking for electric vehicles will encourage carsharing to be electric. Free parking on city streets and in city parking lots is a common incentive in medium-sized cities where the lower density does not create as compelling a business case. Cities could also set aside a certain number of spaces throughout a city solely for electric carsharing vehicles, create signage, tie the number of parking spaces to the number of members in a carsharing service, and create special ticketing authority for traffic enforcement as has proven successful in Madrid and Copenhagen.

Provide financial support

Although it is true that many local authorities do not have enough money available to fund carsharing schemes and would thus rely on incentives such as parking policies, electrification targets, and public transit integration, financial support has been provided in many instances. For example, the maximum cost of an Autolib' charging station was €50,000 covered by the municipalities and the region. The operator paid an annual €750 fee per parking spot in return for using public space to recoup some of the cost. Similarly, BlueLA, which currently operates 100 electric vehicles and 200 chargers at 40 stations in low-income communities, was made possible through a city and state commitment totaling $2.8 million in charging station rebates and parking credits and $10 million in private investment.

Government support is especially needed in rural areas. The charging network is less dense, transit is less available, and many destinations require a car. Rural carsharing increases accessibility to formerly carless households and could allow households to forego the purchase of a second vehicle. While perhaps less viable in North America, rural carsharing has been successful in Europe with financial support.

Zero emission, low emission or congestion zones

Urban vehicle access regulations such as low emission zones (LEZs), zero emission zones (ZEZs), and congestion charging zones can also aid the deployment of electric carsharing when granting preferential access or waivers or reductions of fees to drive in those zones. Within zero or low emission zones, access to the zone is restricted to vehicles that have low or zero tailpipe emissions. Because electric carsharing cars can access these zones, they have a comparativce advantage over conventional vehicles.

25 City of Berlin, "Berlin Service Portal - Resident Parking Permit," n.d., https://service.berlin.de/dienstleistung/121721/.

Fees that are collected from users of a congestion zone can be waived for electric carsharing cars.

Focus on underserved groups

One of the main goals of carsharing is to provide equal access to goods and services for carless households. Often, those who need a car in less densely populated parts of cities are lower income and carsharing operators will not necessarily cater to those groups unless they are required to do so. BlueLA, which was previously mentioned, focuses on low-income areas. Cities can design regulations determining what share of parking stations are required in low-income or low-density areas. In free-floating carsharing, zones can be created for underserved groups and a requirement created such that a minimum percentage of a carsharing fleet reside in those zones as is done in San Francisco.[26] Additional outreach may be needed for certain groups. Developing electric carsharing schemes in low-income areas can also help increase electric vehicle outreach, develop the public charging network, encourage electric vehicle uptake, and improve air quality.

Community outreach

Community outreach can take multiple forms. Firstly, as exemplified in the BlueLA scheme, local residents can be included in the choice of the carsharing operator or its approval process to make sure that the business model corresponds to residents' needs.[27] When reaching out to residents, governments can make sure to reach out to all groups, especially those with less access to or familiarity with technology like smartphones. Another important outreach aspect is the advertisement of the service and its benefits in order to maximize usage. Local authorities would also benefit from a good communication on parking policies to avoid private car owners parking where they are not allowed, and to clearly explain the goals of the policies so that they do not feel they are unfairly losing parking space.

Transit integration

The goal of carsharing is not to replace public transit but to complement it. To make sure that this is the case, cities can encourage dialog on how to integrate carsharing into transit. Following the Copenhagen example where DriveNow collaborated with Arriva—the largest bus operator in Copenhagen—cities can dedicate parking spots to electric carsharing close to transit hubs (with bus, shared bikes, shared e-scooters, etc.) and facilitate partnerships between public transit and carsharing operators. As another example, Flinkster is a carsharing company that includes electric cars and is owned by Deutsche Bahn, the railway company in Germany. Deutsch Bahn Connect recently developed an application enabling an easy intermodal connection among trains, shared bikes, and shared cars.

Targets for carsharing electrification

Electrifying carsharing significantly increases its environmental and social benefits, and cities have a role to play in encouraging electrification. In addition to the policies previously mentioned, cities can also create carsharing strategies that include mandatory electrification goals. Milan Municipal Council, for instance, has required all

26 Shaheen et al., "Shared Mobility Policy Playbook."

27 Shared-Use Mobility Center. 2019. *Electric and equitable: Learning from the BlueLA carsharing pilot*. Retrieved from https://sharedusemobilitycenter.org/wp-content/uploads/2019/04/NewFile_SUMC_04.15.19.pdf

carsharing vehicles to be electric by 2024. Intermediate steps can be taken such as in Copenhagen where 30% of cars shared must be electric by 2020. In Paris, all one-way carsharing fleets already must be 100% battery electric. Broader internal combustion engine phaseouts are important drivers of electric carsharing. For example, stricter regulations include the ban of all nonelectric vehicles from Paris roads starting in 2030. ICE vehicle phaseout targets including all vehicles have been set in Norway where, starting in 2025, sales of new ICE vehicles will be banned.

Conclusions

This briefing details the experience of electric carsharing in Europe and North America to date and gleans lessons learned from both failures and successes. Electric carsharing is more complicated than conventional carsharing and new strategies are necessary to create successful schemes. Electric carsharing promises to bring multiple benefits to cities that have programs, but to date, much of the promise of electric carsharing has not materialized. In order to realize these benefits, cities can learn from the experiences thus far.

From this research, we make the following conclusions:

Electric carsharing brings multiple benefits to a city. The benefits include a 5%–20% reduction in GHG emissions per carsharing household in North America and Europe. Electric carsharing companies can aid in the installation of chargers that are also available to the public and provide reliable usage to recoup infrastructure investments. Electric carsharing brings many of the benefits of conventional carsharing as well, such as a conservative estimated reduction in VKT per household of between 3% and 36%. For each carsharing car, between five and 24 private car purchases were suppressed or postponed, increasing public parking space availability by similar numbers. From a social equity perspective, formerly carless households can have wider access to goods and services, and programs can increase electric vehicle exposure and charging infrastructure development in lower income areas.

Government support is essential for the success of any electric carsharing program. Although carsharing does not necessarily need financial support in dense urban areas, city policies favoring private car ownership can put carsharing at a disadvantage. Conversely, city policies designed to encourage carsharing to be electric can ensure its success. To ensure success in densely populated cites, parking policies for carsharing must be at least equal to those for private cars. As an enticement for electric vehicles, city parking may be given away as an in-kind contribution. For less densely populated cities and rural areas, city government will likely be required to be an active partner to encourage electric carsharing by providing financial support and aiding in charger installation. Integration with public transit and other modes can also allow carsharing to be an integral part of mobility in a city while reducing conflicts with this mode.

Charging infrastructure must adapt to different business models and fleet sizes. Incorporating electric vehicles into carsharing requires charging infrastructure. The sufficient number of chargers differs based on the business model. Roundtrip station-based carsharing requires approximately one charger per car and one-way station-based charging requires 1.5 to two chargers per car. Although station-based carsharing ensures the availability of electric cars with sufficient battery level, it entails high charging infrastructure costs and, at times, poor optimization of public space because most charging and parking is reserved only for carsharing users. One-way free-floating carsharing uses public charging with the possible addition of parking stations with charging inside a free-floating zone. The recommended minimum for charger density is seven chargers per square km equally distributed throughout the zone. If chargers per car fall to less than 0.4 to 0.6 chargers per car, the public charging network could be increased to reach that ratio.

***Electrification of shared fleets happens in multiple steps**.* As of early 2021, free-floating carsharing is often the most economically viable solution for electric carsharing in densely populated cities compared to roundtrip carsharing. Cities could thus only allow battery electric vehicles for their free-floating operators and only require a certain percentage of roundtrip fleets to be electric. Roundtrip carsharing is more likely to involve trips outside a free-floating zone where charging infrastructure is less developed. When the public charging infrastructure is more developed in the surrounding areas, cities can then require roundtrip operators to be fully electric.