City Climate Finance Gap Fund

GAP FUND TECHNICAL NOTES

PRIMER: IMPLICATIONS OF ELECTRIC VEHICLES FOR URBAN PUBLIC SPACE

DECEMBER 2022

Primer: Implications of Electric Vehicles for Urban Public Space

Gap Fund Technical Note[1]

Key Takeaways

Key takeaways for cities on the need for public charging and its implications for public space include the following:

- Public charging must be part of a city's electric mobility strategy, to both accommodate and encourage a transition from internal combustion engine vehicles to electric vehicles. While a private market for electric charging may eventually develop, in most cities public authorities will have to play a leading role early in the transition.
- Cities should project the need for public charging infrastructure based on factors including the housing mix, commuting mode share, vehicle types, shares of fast and slow chargers, and others. Cities should accordingly develop plans to increase the availability of public chargers, siting them to maximize their accessibility and utility.
- Land value capture instruments could help reduce the public cost of provision of charging stations.
- The development of on-street EV charging infrastructure should be part of a broader parking strategy that aims at containing the amount of public space allocated to private cars.

Introduction

Electrification of transport is an essential component of urban climate change mitigation. Transport is responsible for around a quarter of global greenhouse gas emissions. Emissions from the transport sector could double by 2050 in a business-as-usual scenario.[2] An estimated 21% of the emissions reductions necessary to bring urban emissions down to nearly net-zero are in the

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[2] Sustainable Mobility for All. 2021. Sustainable Electric Mobility: Building Blocks and Policy Recommendations. Washington DC, License: Creative Commons Attribution CC BY 3.0

transport sector.[3] Reducing emissions from urban transport primarily involves reducing dependence on private vehicles, through modal shifts to low-emissions alternatives, changes in urban form to reduce transport demand, and other actions.[4] However, given that private vehicles will never completely disappear, a shift towards electric vehicles can help private vehicles reduce their carbon emissions (contingent on the decarbonization of electricity). According to the International Energy Agency, if the growth in electric vehicles experienced in recent years is sustained, CO_2 emissions from cars can be put on a path in line with the 'Net Zero Emissions by 2050' Scenario.[5]

A transition to electric mobility requires adequate public charging infrastructure for private vehicles, which not only accommodates electric vehicles already in operation but can also play a significant role in encouraging their adoption.[6] Cities face various challenges related to providing adequate public charging infrastructure, including the provision of urban space for such infrastructure. This note discusses the implications of private electric vehicle charging on urban public space and how cities can anticipate them in order to facilitate the transition towards electric mobility. This note focuses on private vehicles. While cities also do face challenges in charging *public* electric vehicles, these challenges are different in nature and are beyond the scope of this discussion. This note also focuses specifically on the challenges around the availability of urban space for charging private vehicles. There are several other challenges related to charging electric vehicles, e.g., electric grid capacity, interoperability of charging equipment, and others, but these have been discussed elsewhere and are beyond the scope of this note.

Background

A large-scale shift towards electric mobility appears imminent. In 2020, the global number of electric cars exceeded 10 million for the first time. This is a more than fivefold increase in just five years.[7] This still represents only 1% of the total stock of vehicles, with the largest stocks being in

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[3] Coalition for Urban Transitions. 2019. *Climate Emergency, Urban Opportunity*. World Resources Institute (WRI) Ross Center for Sustainable Cities and C40 Cities Climate Leadership Group. London and Washington, DC. https://urbantransitions.global/urban-opportunity/

[4] Jaramillo, P., S. Kahn Ribeiro, P. Newman, S. Dhar, O.E. Diemuodeke, T. Kajino, D.S. Lee, S.B. Nugroho, X. Ou, A. Hammer Strømman, J. Whitehead, 2022: Transport. In IPCC, 2022: *Climate Change 2022: Mitigation of Climate Change*. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [P.R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, J. Malley, (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA. doi: 10.1017/9781009157926.012

[5] IEA (2022), Electric Vehicles, IEA, Paris https://www.iea.org/reports/electric-vehicles, License: CC BY 4.0

[6] Li, S. et al. (2021). "The Global Diffusion of Electric Vehicles: Lessons from the First Decade." Policy Research Working Paper; No. 9882. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/36740

[7] Electric vehicle sales and stock figures in this paragraph refer to both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs). Globally, BEVs accounted for two-thirds of new electric car registrations and two-thirds of the stock in 2020, and are also expected to account for around two-thirds of the electric car stock in 2030. The issues around charging in this note are more acute for BEVs than for PHEVs, as the latter can switch to their internal combustion engine when not charged, though this diminishes the environmental and cost benefits of electric vehicles.

China and Europe. There are still only three electric vehicles (EVs) per 1000 people in China, and fewer than ten per 1000 people in the United States and large European countries such as the United Kingdom, France, and Germany.[8] However, EV sales targets by automobile manufacturers and net-zero emissions targets from governments suggest that a significant shift towards electric mobility is likely (Figure 1). In June 2022, the European Parliament vowed to ban new fossil-fuel cars after 2035. In August 2022, the United States introduced new tax credits for electric vehicles. Even before these latest legislative changes, the International Energy Agency projected that by 2030, EVs would account for between 7% and 12% of the global vehicle stock and between 15% and 35% of new vehicle sales, excluding two- and three-wheelers. Between 30% and 40% of the global stock and 50-75% of new sales of two- and three-wheelers are expected to be electric in 2030.[9] In low- and middle-income countries, the total stock of vehicles is also increasing along with economic growth. By 2030, there are projected to be between 125 and 200 million electric cars in the world.[10]

[8] "Electric cars per population in leading countries worldwide 2020." Statista, August 2021. https://www.statista.com/statistics/1256609/electric-cars-per-population-worldwide/
[9] International Energy Agency (2021). *Global EV Outlook 2021: Accelerating ambitions despite the pandemic.*
[10] International Energy Agency (2021). Global EV data explorer. https://www.iea.org/articles/global-ev-data-explorer

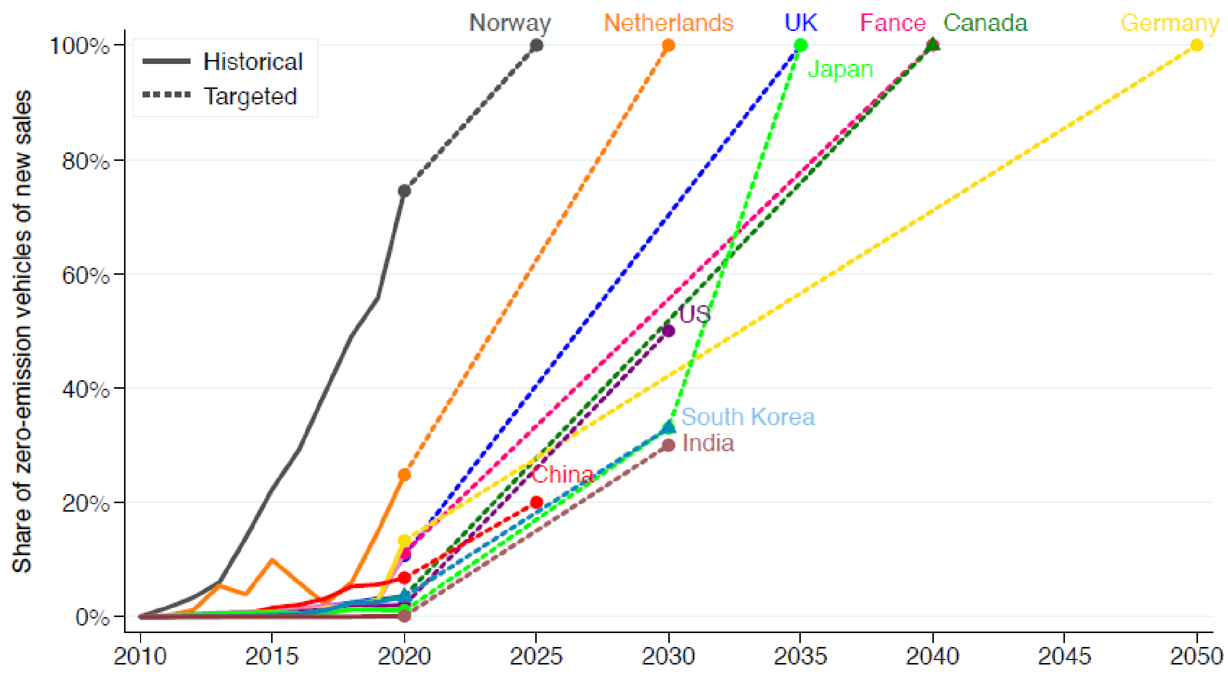

Figure 1: Zero-emission vehicle market shares and targets (Source: Li et al., 2021)[11]

Electric charging vs. refueling of internal combustion engine vehicles

In order to discuss the spatial implications of electric charging for cities, it is important to understand two key differences between electric charging and conventional refueling.

First, electric charging is slower than refueling of conventional vehicles. Charging an electric vehicle takes much longer than refueling an internal combustion engine (ICE) vehicle. While refueling takes only a few minutes, most EV chargers take between 30 minutes and 14 hours to supply 80 miles (~130 km) of driving range, depending on the vehicle, the charging infrastructure available, and the user's willingness to pay.[12] The fastest charging presently available is exclusively for Tesla cars at "supercharging stations," which can provide a range of up to 200 miles (322 km) in 15 minutes. While improvements in technology mean that faster charging will be possible in the future, limitations in terms of affordability, safety, and grid capacity mean that it is unlikely that fully charging an EV will ever be as fast as fully refueling an ICE car for most EV users.[13] This is particularly true in low- and middle-income countries. E.g., in India, fast chargers are projected to represent only around 2% of

[11] Li, S. et al. (2021). "The Global Diffusion of Electric Vehicles: Lessons from the First Decade." Policy Research Working Paper; No. 9882. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/36740

[12] Fitzgerald, Garrett and Chris Nelder. *From Gas to Grid: Building Charging Infrastructure to Power Electric Vehicle Demand.* Rocky Mountain Institute, 2017. https://www.rmi.org/insights/reports/from_gas_to_grid

[13] Stone, M. (2021). "Will charging electric cars ever be as fast as pumping gas?" *National Geographic.* https://www.nationalgeographic.com/environment/article/will-charging-electric-cars-ever-be-as-fast-as-pumping-gas

publicly accessible chargers by 2030.[14] For the foreseeable future, EV charging requires a vehicle to be parked for some time, unlike drive-through refueling of ICE cars. (An alternative to charging is battery-swapping, which can be done quickly, but this has not been widely adopted by vehicle manufacturers, especially for cars and larger vehicles as opposed to two- and three-wheelers.)

Second, electric charging is more spatially dispersed than refueling of conventional vehicles. Unlike refueling an ICE car, which is mostly done at dedicated locations, EV charging can be done anywhere that has a suitable connection to the electric grid.[15] Charging infrastructure is small enough that it can usually be installed where cars normally park. Home chargers are typically just cables, while public chargers require a buffer of around half to one meter on one side of a parking space to accommodate a wall-mounted or pedestal-mounted charging point.[16] Figures Figure 2 and Figure 3 show sample layouts for off- and on-street parking equipped with EV chargers.

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[14] International Energy Agency (2021). Global EV data explorer. https://www.iea.org/articles/global-ev-data-explorer

[15] Providing sufficient electric grid capacity, particularly for fast charging, is a considerable challenge in itself, but one that is not explored in detail in this note.

[16] Government of India and WRI India (2021). *Handbook of electric vehicle charging infrastructure implementation – Version 1.* https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pdf

CHARGING LAYOUT FOR OFF-STREET PUBLIC PARKING

CHARGING INFRASTRUCTURE INSTALLATION WITH 6 CHARGERS
2 nos. DC chargers-1 x 25 kW (CCS2 and Chademo)
4 nos. AC chargers- 1 x 3.3 kW (industrial socket)

4 EV parking bays- 2.5m x 5m each
2 bays for e-cars, 2 bays for e-scooters/e-autos

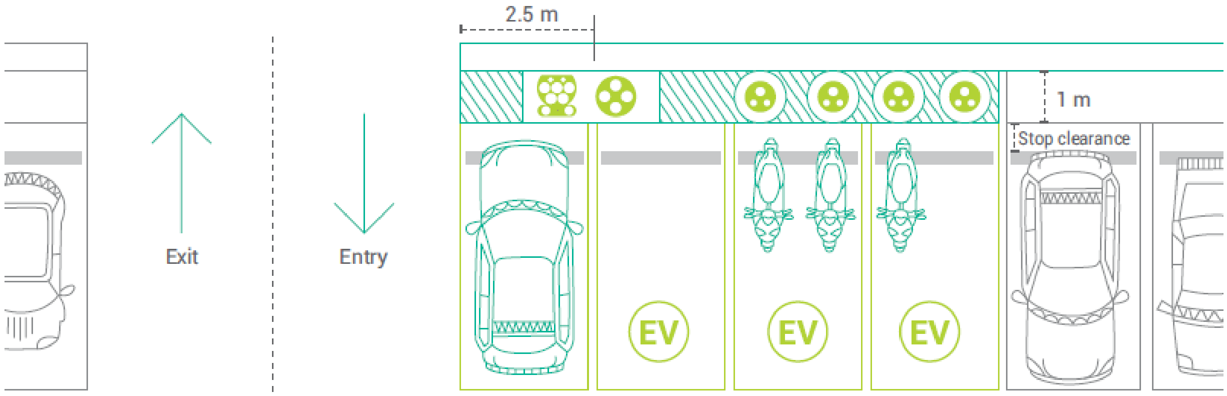

Figure 2: Charging layout for off-street public parking (Source: Govt. of India and WRI India, 2021)[17]

CHARGING LAYOUT FOR ON-STREET PUBLIC PARKING

CHARGING INFRASTRUCTURE INSTALLATION WITH 6 CHARGERS
2 nos. AC charger- 1 x 7.4 kW (Type 2 connector)
4 nos. AC chargers- 1 x 3 kW (industrial socket)

6 EV on-street parking bays
2 nos. e-car bays- 2.5m x 5.5m
4 nos. e-scooter bays- 2.5m x 1.4m

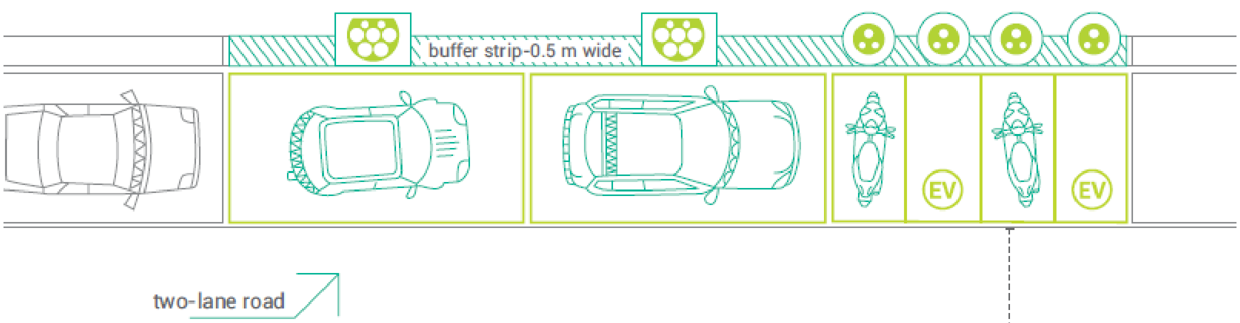

Figure 3: Charging layout for on-street public parking (Source: Govt. of India and WRI India, 2021)[18]

The importance of public charging

Due to the time needed to charge EVs, wherever possible, most charging of private EVs will be done at home or at work. Fleets of electric vehicles (buses, taxis, delivery vehicles, etc.) may also have dedicated charging facilities at depots.

However, there remains an important role for public charging infrastructure.[19] Not every prospective EV owner will have access to charging infrastructure at home. Apartment buildings are less likely to have EV charging infrastructure compared to single-family houses, due to uncertainty about usage, complexity of cost-sharing among tenants, and concerns (whether legitimate or not) about them being a fire hazard if placed in parking garages. In China, nearly 40% of chargers are public, in response to the large share of urban residents living in apartment buildings.[20]

Similarly, not all EV users will have regular access to charging at work. Increasingly, many people work from home for at least part of the week. Even if workers do go to a traditional workplace and it does have charging infrastructure, they may not necessarily drive to work every day, preferring to use other modes or to carpool. (In fact, if the main charging location of an EV owner is the workplace, this creates an incentive for him or her to drive to work instead of taking public transport, walking, or biking, which would increase energy use, traffic congestion, and other negative consequences of private vehicle use.) Even if users have access to charging at home or work, public chargers will remain necessary for EVs to drive to locations far from these locations.

In addition to meeting this demand, the visibility of public EV chargers also plays a significant role in encouraging adoption of electric vehicles through their "demonstration effect", particularly during the current early stage of EV adoption, assures prospective EV buyers that chargers will be available. The visibility of public chargers helps quell what is sometimes called "range anxiety *anxiety*", i.e., the fear among potential EV buyers that they would experience "range anxiety" (which in turn is the fear while driving of running out of battery before reaching one's destination). A recent World Bank study demonstrates that across 13 wealthy countries, subsidizing charging infrastructure is correlated with a greater increase in EV sales than subsidizing vehicles themselves, which emphasizes the importance of this demonstration effect.[21] For these reasons, the availability of public charging is likely to be essential to encourage and accommodate EV adoption. If this demand for public charging is not met, it could prevent the widespread adoption of EVs.

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[19] Public charging in this document refers to any EV charging that is accessible to the public without restrictions, even if it is operated by a private entity and is on private land. For example, by this definition a public charging station in the parking lot of a shopping mall or restaurant is 'public' if anyone can use it, but not public if it is only available to customers of that business.

[20] National Resources Defense Council et al. (2020). *Scaling Up Electric Vehicle Charging Infrastructure: Lessons from China and the United States for the Indian Context.*

[21] Li, S. et al. (2021). "The Global Diffusion of Electric Vehicles: Lessons from the First Decade." Policy Research Working Paper; No. 9882. World Bank, Washington, DC. https://openknowledge.worldbank.org/handle/10986/36740

Implications of public charging for urban space

Public authorities may need to play a greater role in encouraging EV adoption during early stages of the transition to electric mobility, before a private market for providers has matured. In recent years, energy and transport specialists have focused on several issues around the public provision of EV charging infrastructure. Key issues include the need for adequate electrical grid capacity, a regulatory framework for the operation of charging infrastructure, the management of varying technical standards for charging equipment, and cost recovery of financial investments in public charging stations.[22]

However, an implication of the need for public EV charging stations that has received less attention is the increased demand for public space in dense urban areas that are already spatially constrained. The importance of public charging means that the number of vehicles that need to park in a third (non-home, non-work) location for up to several hours at a time could increase substantially. This is particularly true in cities or neighborhoods in which a large share of the population lives in apartment buildings without charging points for residents. If a resident who today parks his or her ICE vehicle in a garage in such a building switches to an EV, he or she would have to park at a public charging station at least once every few days.[23] A dense network of public charging stations would need to be built to meet this potential demand.

While public charging stations will be similar to gas (petrol) stations in some ways, they will require more parking space. As discussed above, while the fastest charging can be similar to conventional refueling, most charging in the foreseeable future will involve parking for extended periods. Shops, restaurants, gyms, co-working spaces, and other businesses may co-locate with these charging stations to keep users occupied while their cars charge, taking advantage of this "captive" customer base. Charging "lounges" offering users amenities while they wait for their cars to charge are currently being developed in North America.[24] These amenities can provide a revenue stream to help offset the cost to service providers, but would also add to the spatial requirements. Chargers can be installed in the parking spaces associated with existing businesses, but this parking may not be sufficient for cars to park for several hours.

Alternatively, curbside (on-street) parking spaces throughout the city may be equipped with chargers. However, this will not satisfy demand if people who are currently using off-street parking (e.g., in residential buildings which do not have sufficient EV charging infrastructure) buy EVs and start to use these curbside parking spaces instead. In dense urban centers, providing a sufficient number of charging facilities or curbside chargers throughout the city has already been a

[22] González-Salas, A. et al., (2021). *Transport Electrification: Regulatory Guidelines for the Development of Charging Infrastructure*. Inter-American Development Bank, 67. http://dx.doi.org/10.18235/0003383

[23] MRC Group and Hubject Consulting (2021). "Deployment of Electric Vehicle (EV) Charging Infrastructure and Incentives to Support the Scale Up of Electromobility Technologies in Turkey: Task-1 Report." Version 1, 11 November 2021.

[24] Motavalli, Jim. (2022). "Charging Lounges Help Make Plugging In a More Palatable Experience." Autoweek, June 2. https://www.autoweek.com/news/a40156968/ev-charging-lounges-plugging-in-experience/

challenge.[25] Cities could mandate the installation of charging points in off-street parking, although this may not be feasible everywhere.

As noted above, the adoption of electric two- and three-wheelers is likely to exceed the adoption of electric cars, especially in low- and middle-income countries. In cities with large numbers of electric two- and three-wheelers, battery-swapping stations could become more popular. These would also require urban space, though less than car charging stations.

Preparing urban public space for electric charging

Projecting future needs

Cities aiming to address the challenge of public EV charging have often begun by estimating the potential need for public charging. Figure 4 shows statistics on public charger availability in selected cities in China, Europe, Japan, and the United States. However, current patterns of EV usage, e.g., in terms of public chargers per vehicle, are not necessarily a good guide to future need. This is because current usage reflects the behavior of early adopters, who disproportionately consist of those who have access to charging at home or at work and rely less on public chargers. Future supply will have to accommodate not only a larger number of users but also potentially a larger share of users without access to chargers at home or work. Generic guidelines and targets are available for the need for public chargers. For example, national targets for curbside chargers range from one connection per 100 vehicles to one connection per 2-3 vehicles. The lowest target for charging stations is one connection per 500 vehicles.[26] European Union legislation from 2014 recommended 10 EVs per public charger.[27] Figure 4 shows that Chinese cities have lower (i.e., better) ratios than this benchmark, while cities in the US and Northern Europe have higher ratios, likely due to the higher share of single-household residential buildings in the latter countries.

[25] Ulrich, L. (2020). "'Charger desert' in big cities keeps electric cars from mainstream." *New York Times*. April 16. https://www.nytimes.com/2020/04/16/business/electric-cars-cities-chargers.html
[26] González-Salas, A. et al., (2021). *Transport Electrification: Regulatory Guidelines for the Development of Charging Infrastructure.* Inter-American Development Bank, 67. http://dx.doi.org/10.18235/0003383
[27] International Energy Agency (2022). *Global EV Outlook 2022: Securing Supplies for an Electric Future*

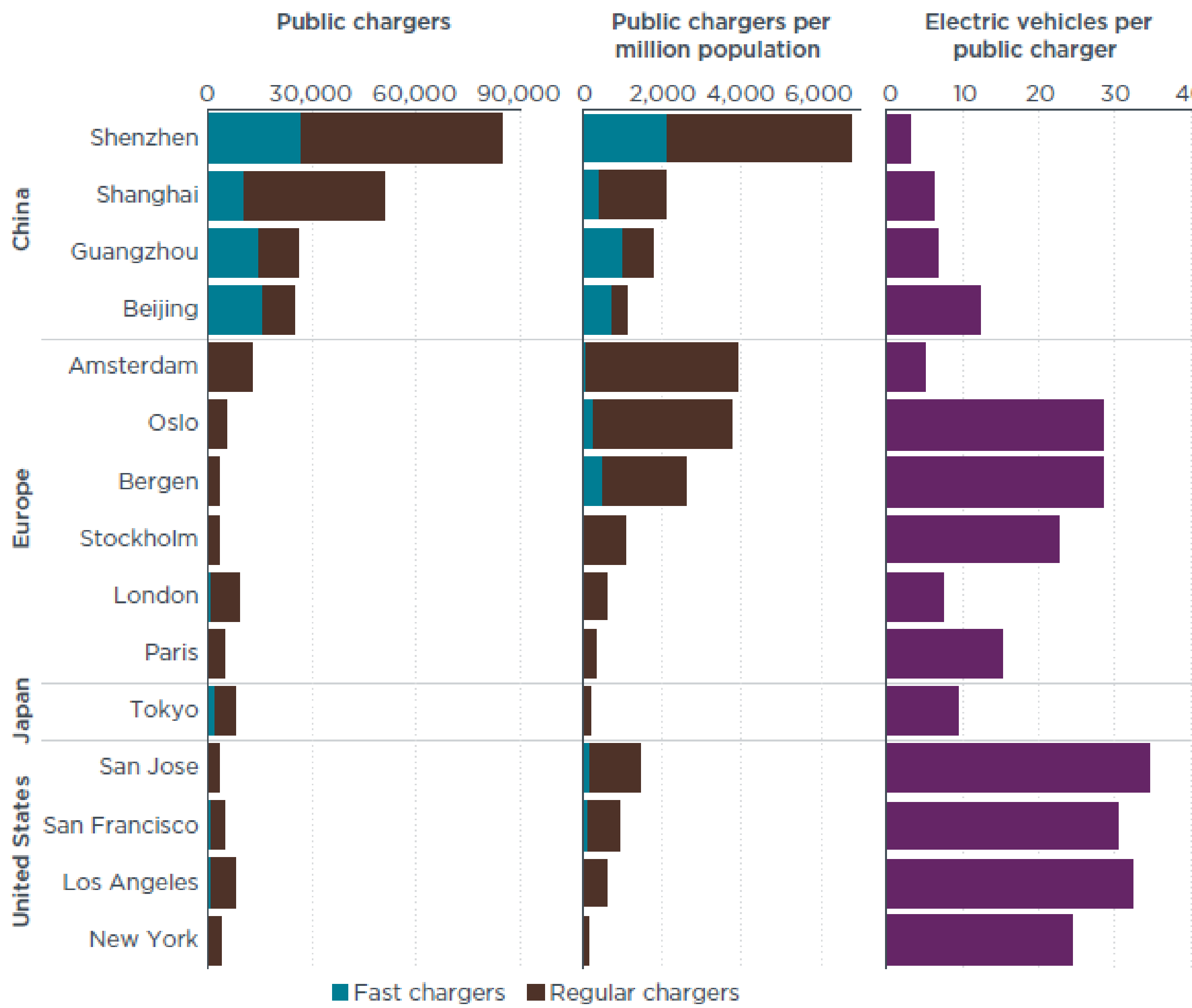

Figure 4: Public charging infrastructure deployment in selected cities (Source: Hall et al., 2020)[28]

The needs of a particular city depend on its specific characteristics. According to the International Council on Clean Transportation (ICCT),[29] factors which impact the quantity and type of public chargers that a city will need include:

- Housing stock: A higher share of potential EV users living in apartment buildings typically would mean less access to home charging, and therefore a greater need for public charging.
- Commuting mode shares: A higher share of commuters using public transport, walking, or bicycling would mean lower potential for workplace charging, and therefore a greater need for public charging.

[28] Hall, D. et al. (2020). "EV Capitals - Cities aim for all-electric mobility." International Council on Clean Transportation Briefing. September 2020.
[29] Hall, D. and Lutsey, N. (2020). "Electric vehicle charging guide for cities." International Council on Clean Transportation Consulting Report.

- Vehicle mix: Battery electric vehicles require fast charging, while plug-in hybrid vehicles generally do not.
- Driving patterns: Average trip lengths will influence charging needs.
- Share of DC fast chargers: A greater share of fast chargers reduces the total number of chargers needed.

Cities around the world have modeled future demand for public charging. For example, a model used to forecast charging infrastructure demand used for cities in Turkey considered current and projected regulations and incentives, electricity and oil prices, population, income distribution, vehicle costs, housing patterns, and electrical grid limitations. When applied to Istanbul, this model projected the need for around 10,000 additional public chargers by 2030.[30] A model used in India considered projected EV sales in different vehicle segments, daily distance driven by each vehicle segment, battery capacity and driving range per charge, the share of charging done using public chargers, and charger types, to estimate the need for public chargers. When applied to Bengaluru, it estimated a need for around 16,300 public chargers (of which around 9,800 would be for three-wheelers, 3,900 for two-wheelers, 2,300 for commercial cars, and only 300 for personal cars).[31]

Integrating public charging into land use and infrastructure plans

Assessing future demand can help a city develop a charging infrastructure plan. The steps that the ICCT recommends in the development of such a plan are outlined in Figure 5.

[30] MRC Group and Hubject Consulting (2021). "Deployment of Electric Vehicle (EV) Charging Infrastructure and Incentives to Support the Scale Up of Electromobility Technologies in Turkey: Task-1 Report." Version 1, 11 November 2021.

[31] Government of India and WRI India (2021). *Handbook of electric vehicle charging infrastructure implementation – Version 1.* https://www.niti.gov.in/sites/default/files/2021-08/HandbookforEVChargingInfrastructureImplementation081221.pdf

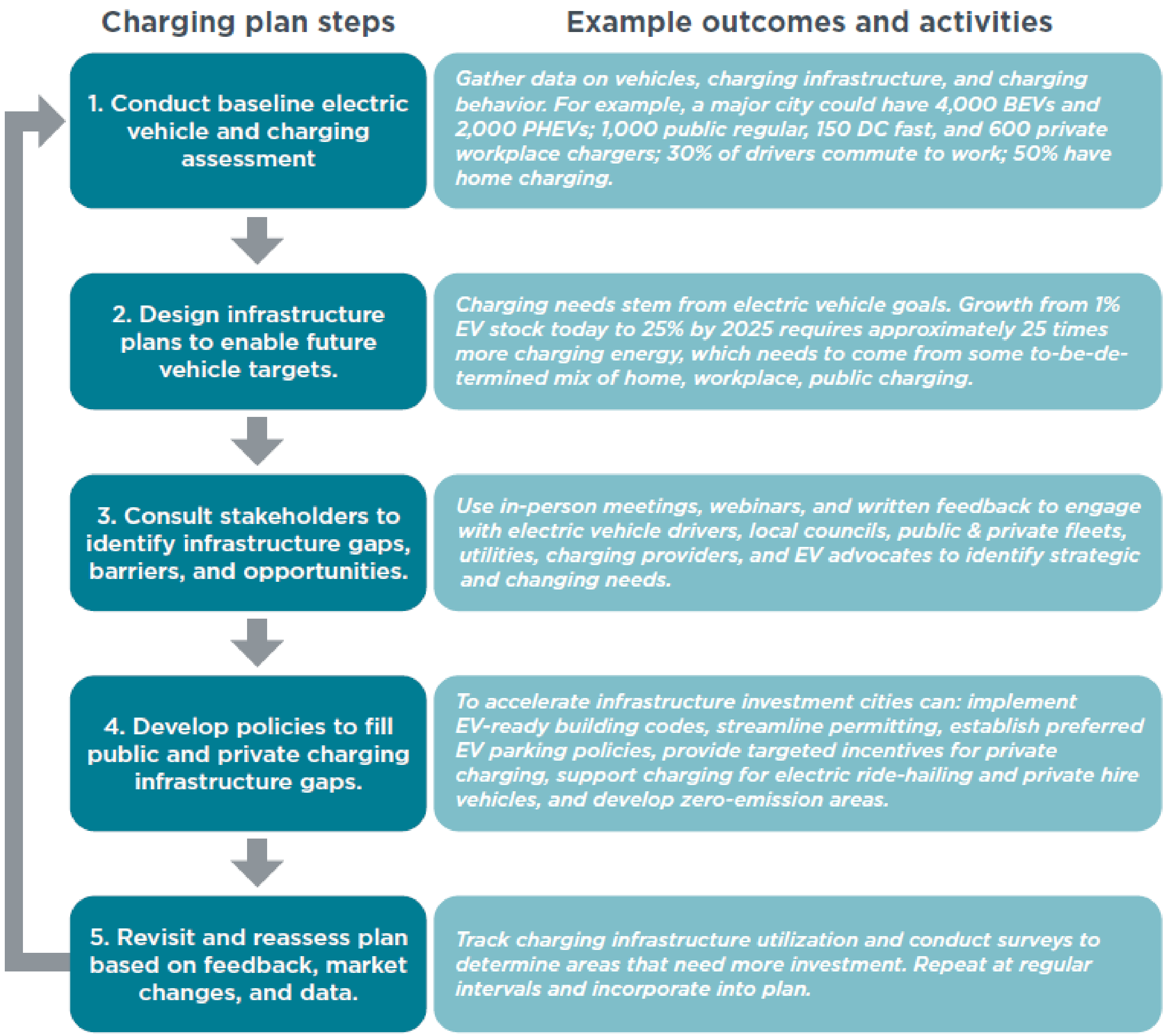

Figure 5: Template for creating a charging infrastructure plan (Source: Hall and Lutsey, 2020)[32]

Models and planning processes such as those described above can help to determine, in addition to the need for charging infrastructure and electrical grid capacity, what this projected future demand would mean in terms of the quantity and location of public land. Accordingly, land could be set aside in land use plans for this charging infrastructure. Siting charging stations appropriately is important. In China, public charging infrastructure is increasingly available, but the current utilization rate is low, suggesting that charging stations may not be optimally located.[33]

[32] Hall, D. and Lutsey, N. (2020). "Electric vehicle charging guide for cities." International Council on Clean Transportation Consulting Report.

[33] National Resources Defense Council et al. (2020). *Scaling Up Electric Vehicle Charging Infrastructure: Lessons from China and the United States for the Indian Context.*

Ensuring that private EVs do not take over public space

Planners often advocate against the overprovision of parking spaces for private vehicles, particularly free parking on public land. Free on-street parking effectively subsidizes, and therefore incentivizes, private vehicle ownership. Even minimum off-street parking requirements for new private developments can have negative effects. For example, they cause buildings to be surrounded by large parking lots, which reduces urban density, reducing the viability of public and nonmotorized transportation. They also increase the land required for new development, which increases development costs. These costs are passed on to all users of those developments (residents, customers, etc.), not only those who drive.[34]

The provision of EV charging stations can also have some of the same negative effects as parking spaces. Particularly as EVs are currently more expensive than ICE vehicles, dedicating public space for an amenity that is associated with wealthier residents may be unpopular among non-EV users and create a backlash against EVs. This is why it is important to integrate public charging stations into a broader land use and transportation plan that prioritizes public transport, micro mobility, nonmotorized transport, transit-oriented development, and parking management through appropriate pricing.

The need for public electric vehicle charging could also be an opportunity to regulate parking and vehicle use. In many cities in low- and middle-income countries, parking is relatively unregulated, especially that of two- and three-wheeled vehicles, which results in vehicles blocking streets, bicycle lanes, and pedestrian pavements. If properly planned, the need for vehicles to park in specific spaces to avail themselves of charging infrastructure could provide an opportunity for authorities to prevent unregulated parking, and charge for parking where it was previously unable to. When electric vehicles are widely adopted, this could also allow authorities to manage vehicle use, e.g., by regulating the availability or price of public charging infrastructure in certain zones during certain hours.

Acquiring land for public chargers

Local governments aiming to increase the availability of public chargers without incurring high land acquisitions costs can start by installing public chargers on existing public land, e.g., at government buildings. This has been done in South Korea[35] and is currently being done in India.[36] However, this is only a first step, as public land may not be available everywhere that chargers are needed.

The cost of acquiring land in dense cities can be a barrier to the provision of public chargers. However, in places where public chargers are seen as an amenity to neighboring residences and businesses, they will eventually raise the land value of surrounding property. This suggests the possibility of using land value capture instruments to help defray public costs. For example,

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[34] Shoup, D., (2021*). The High Cost of Free Parking*. United Kingdom: Taylor & Francis.

[35] Brown, J. L. (2022). "Electric Vehicle Charging: Lessons from the Republic of Korea." Presentation, May 2022.

[36] National Resources Defense Council et al. (2020). *Scaling Up Electric Vehicle Charging Infrastructure: Lessons from China and the United States for the Indian Context*.

development charges could be levied on private property developers in the vicinity, or public charging stations could be jointly developed by private developers and public authorities, so that those that benefit from proximity to public chargers also help shoulder some of their upfront costs.[37] Land readjustment, also sometimes used as a form of land value capture, is another tool that can be used to acquire land for public charging stations without incurring high land costs. This involves a group of landowners giving up a portion of each of their properties for free in order to create room for infrastructure, in this case public charging infrastructure, in anticipation of their value of their properties increasing as a result of the infrastructure, despite their properties now being smaller. Realistically, the complexity of applying these tools means that their use is probably only justified if large charging stations accommodating many vehicles need to be installed in very densely built-up cities with high land values.

Looking ahead

For now, the future remains uncertain. In the best-case scenario, the need for urban space for public charging will not present a significant barrier to the adoption of EVs in cities. This may occur in a variety of ways. The need for public charging could reduce as a result of residential and commercial property developers providing sufficient charging infrastructure in residential and office buildings. This could happen in response to incentives, subsidies, regulations, or user demand. Another possibility is that charging stations and the commercial developments surrounding them are seen as lucrative enough that private businesses build them even in dense urban environments, despite the cost and complexity of acquiring the necessary land. A recent analysis in New York found that monetizing indirect value from retail sales increased charging stations' profitability by up to 250%.[38] A third possibility is that advances in battery and charging technology may make fast charging cheaper and safer, which would minimize the need for public charging, or allow public charging to occur as quickly as refueling. Yet another possibility is that battery-swapping could become much more popular than it currently is, which would eliminate the need for recharging.

However, cities cannot count on these changes occurring. There is a "chicken-and-egg" quality to some of these changes: private operators and property developers may not invest in charging infrastructure until there is enough EV adoption to justify the expense and effort, while potential EV users may not buy EVs until there is widespread charging infrastructure. For these reasons, cities should assume that public charging will be needed and prepare accordingly. This includes ensuring that a lack of urban space for public charging does not act as a bottleneck for EV adoption in coming years.

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[37] Ang, G. and V. Marchal (2013), "Mobilising Private Investment in Sustainable Transport: The Case of Land-Based Passenger Transport Infrastructure", OECD Environment Working Papers, No. 56, OECD Publishing. http://doi.org/10.1787/5k46hjm8jpmv-en

[38] Center for Climate and Energy Solutions, *Strategic Planning to Implement Publicly Available EV Charging Stations: A Guide for Businesses and Policymakers*. 2015.