JANUARY 2020

ISSUE BRIEF

LOCATION IS EVERYTHING: APPROACHES TO SITING ELECTRIC VEHICLE CHARGING INFRASTRUCTURE FOR THE INDIAN CONTEXT

EXECUTIVE SUMMARY

In India, increasing the fleet of electric vehicles (EV) and charging infrastructure will be key to improving air quality in cities, enhancing energy security (by reduced dependence on imported crude), and fighting climate change. The national government is also moving toward a massive scale-up of renewable energy and sustainable mobility (e-mobility). Several states and cities along with private companies are moving forward with electric mobility plans in India. As per an analysis by Niti Aayog and Rocky Mountain Institute, 30% EV penetration by 2030 will generate an estimated saving of up to 474 million tons of oil equivalent (Mtoe) and 846 million tons of net CO_2 emissions over their lifetime.[1]

	Local Knowledge Stakeholder Approach	Modeling Approach	Hybrid Approach
Planning area	Small to medium	Medium to large	Medium to large
Key resources needed	Local knowledge and participation	Comprehensive data base and modeling expertise	Mix of both
Most cost-heavy procedure	Numerous workshops and human cost	Data acquisition and analysis	Mix of both
Time consuming procedure	Iterative discussion and engaging stakeholders	Data processing and interpretation	Mix of both
Advantage	Easy to start and manage without needing substantial data or modeling expertise, better community acceptance	Generally requires less time and human cost, can handle large scale planning, better planning transparency	Saves time with modeling, do not need as much data and modeling capacity as pure modeling approach, which can be compensated by stakeholder engagement
Disadvantage	Hard to manage when planning area gets bigger, hard for human decisions to cover complicated planning objectives consistently	A comprehensive database may not be available or expensive to acquire, models are subject to caveats	Can be tricky to decide how modeling and human decisions should be synergized, and where should either approach be used

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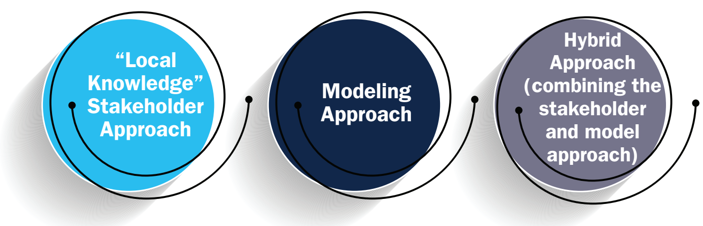
One of the main factors hindering rapid EV adoption is range anxiety, the fear of running out of battery power before being able to recharge. This concern is amplified in areas with limited charging infrastructure. Lack of charging infrastructure and its high deployment cost given the price sensitive Indian market is a major deterrent. Also, having an electric vehicle which is equivalent to an internal combustion engine vehicle in performance and pricing remains key to expanding electric mobility. To accelerate EV usage in India, thirteen states and union territories (UT) are leading the way in building production, services, and infrastructure.[2] Most states in India have initial programs for installing charging infrastructure in public and private places. A sound charging infrastructure plan involves many players. It includes representatives from various levels of government, local business owners, land developers, public utilities, institutions, resident welfare associations, vehicle associations and the public, especially EV owners. As India moves forward with implementing EV policies, a key question among city planners is “how to site and locate charging infrastructure” in the Indian context.

This issue brief provides decision-makers and stakeholders with information on the principles of charging infrastructure location and siting. It also presents successful EV adoption approaches that have been used by cities in other parts of the world. In addition, based on international practices, this issue brief presents three approaches to siting EV charging infrastructure:



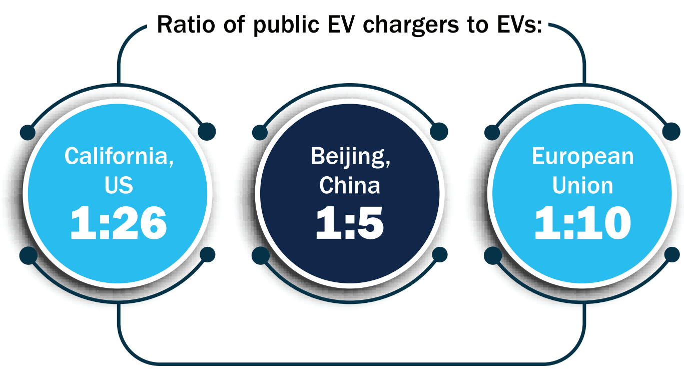
An advantage of the hybrid approach is that it makes initial planning for bigger areas more manageable by employing a small group of modelers, rather than a large gathering of stakeholders. In the later phase before implementation, stakeholder engagement and local knowledge will still be needed to fill in the gaps between the modeling results and reality.

Given the local context with active stakeholder involvement and limited data, the hybrid approach is an appealing approach for Indian cities.

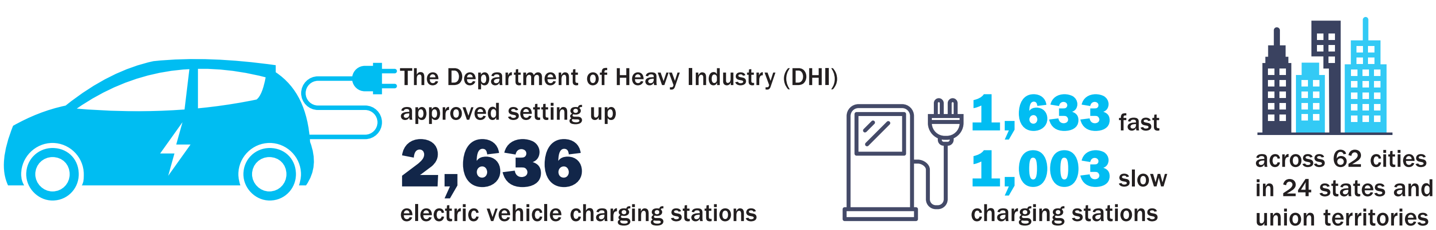
OVERVIEW OF CHARGING INFRASTRUCTURE IN INDIA

India aims to expand its electric mobility market, yet the development of EV charging infrastructure, also known as EV supply equipment (EVSE), remains in the early stages. A robust charging infrastructure is crucial for EV market growth, and a healthy ratio between the number of EVs to charging stations is important to encourage early adopters and relieve drivers of range anxiety.

India is estimated to have approximately 500 public EV charging stations and is in early stages of developing charging infrastructure.[3] In January 2020, the Department of Heavy Industry (DHI) approved setting up 2,636 electric vehicle charging stations (1,633 fast and 1,003 slow charging stations) across 62 cities in 24 states and union territories in the country under the FAME II scheme.[4] A strong public charging system is needed to support robust EV use. For example, the State of California in the United States is considered an EV leader and has 19,687 public charging units and 506,608 EVs on the road, a 1:26 ratio.[5] In an even denser city like Beijing, China, the ratio between EV chargers and EVs has reached 1:5 ratio[6], and if private chargers are counted, 1:1.5 ratio.[7] The European Commission directed EU countries to set EVSE deployment targets for 2020 and 2025 to match the level of infrastructure required by the EU Alternative Fuels Infrastructure Directive (2014).[8] Targets include establishing one publicly accessible charging outlet for every 10 cars by 2020.



The Indian government has made strong progress to spur transportation electrification with national and state EV plans. Yet, a gap remains in charging infrastructure. Both capital investments and installations are needed to achieve state and national ambitions. For example, state-run Energy Efficiency Services Limited (EESL), tasked with procuring



10,000 EVs for government use, cited that they could not meet the goal, due to a lack of charging infrastructure.[9]

To accelerate EV adoption, the Government of India launched the incentive scheme, Faster Adoption and Manufacture of (Hybrid and) Electric vehicles (FAME II), under the umbrella of the National Electric Mobility Mission Plan. For projects that meet specific requirements, up to 100 percent of the charging infrastructure equipment cost could be funded. At the national level, the Ministry of Power (MoP) developed "Charging Infrastructure for Electric Vehicles – Guidelines and Standards." The guidelines require that charging infrastructure conform to a set of standards for ease of use and be compatible with multiple existing charging standards.

IMAGE CREDITS: CHARU LATA, NRDC

To expand the EV market, the national government and leading states are determining the locations of the charging infrastructure. For example, in the Guidelines and Standards from MoP, location factors are explicitly included in the document, which states "at least one charging station should be available in a grid of 3 km by 3 km, and one charging station should be set up at every 25km on both sides of highways/roads." In July 2019, the Department of Heavy Industry, issued an Expression of Interest, inviting installation of charging stations in cities with populations over one million, satellite towns connected to the seven major metropolitan regions, and other cities meeting certain criteria.

As policymakers establish incentives and programs, one crucial question is where to logistically have initial charging infrastructure placements, followed by increased growth. Based on international best practices, two key considerations are charging station density and economic feasibility. It is common that the government planning leads the planning process. A private actor may want to plan for its own charging network, which usually still needs the support or approval of the government.

Public entities can invest in and build charging infrastructure, like EESL in India. Public-Private-Partnerships (PPPs) are also common. PPPS are best suited for when the government wants to maintain the charging infrastructure as a public good, yet needs market expertise and financial resources. As a public good, the government can apply public policy tools more easily, such as price control for affordability, and provide charging in low-utilization areas for better charging coverage.

Takeaway point: PPPs are best suited for when the government wants to maintain the charging infrastructure as a public good, yet needs market expertise and financial resources. As a public good, the government can apply public policy tools more easily, such as price control for affordability, and provide charging in low-utilization areas for better charging coverage.

Private actors, such as local business owners and specialized charging providers, can work on their own for-profit stations and deploy charging infrastructure sometimes more quickly than public chargers. This is especially common for battery swapping stations.[10] For example, there have been working business models where the company sells e-scooters and establishes battery switching stations to service their e-scooter users and charge a fee like Gogoro's business model in Taiwan.[11] Ultimately, private sector stations will complement the government's plan.

IMAGE CREDITS: CREATIVE COMMONS

LOCATION AND SITING BASICS

Location and *siting* are often used interchangeably but have different meanings. *Location* usually refers to broader areas where a charging station is located, such as around shopping center or movie theaters, whereas *siting* refers to the more specific position within a location, such as a parking spot adjacent to the north entrance of the shopping center. One can think about *location* as a bubble, and a *site* as a point in the bubble.

Location and siting can be framed as: 1) 'Location' is finding suitable areas for charging infrastructure and fitting an adequate number of stations to the areas, so that overall refueling demands are met, and 2) 'Siting' is finding the exact spots for stations, considering site-specific details, including but not limited to cost of connection (including power grid upgrades needed, location charges, etc.), accessibility, visibility, and safety, so that the planned stations can be well utilized and economically feasible. Depending on the planning scope, the planning body can focus on either, or do both sequentially.

THREE APPROACHES TO CHARGING INFRASTRUCTURE LOCATION AND SITING

1. "LOCAL KNOWLEDGE" STAKEHOLDER APPROACH

For smaller communities with limited budgets and/or with limited data availability, a "local knowledge" based approach that engages stakeholders can be an effective methodology to conduct the planning while meeting budget or data constraints. This approach is based on a tool kit developed by the Community Energy Association, *Planning for Electric Vehicle Charging Infrastructure.*[12] The approach involves decision-makers to convene local experts with knowledge on traffic patterns and urban space.

There are four major steps for the "Local Knowledge" Stakeholder Approach: 1) Engage and educate, 2) Determine vision, goals and objectives, 3) Identify preferred locations, and 4) Identify promising sites. Depending on the size of the planning area, and the timeframe of the planning exercise, the identification of locations and sites can be done together.

British Columbia (BC) Toolkit

The British Columbia Toolkit provides useful information on the local knowledge-based approach, *Planning for Electric Vehicle Charging Infrastructure: A Toolkit* by Community Energy Association, sponsored by BC Hydro and British Columbia Ministry of Energy, Mines and Natural Gas. Refer to the original document for more supporting materials and case studies.[13] The toolkit is useful for the Indian context and other regions with limited data and budgetary resources.

STEP 1: ENGAGE AND EDUCATE

To build awareness in the community and raise awareness on charging infrastructure, decision makers work to educate stakeholders, community members, and potential partners on information about EVs, EV charging, and how these matters relate to broader community goals. This step may also help identify local champions and possible partners for EV charging station deployment.

Key stakeholders for an EV planning process include: representatives from local or state government, community business owners (including vehicle dealerships), local land developers and owners, local utility representatives, research and data collection institutions (e.g. Institute for Transportation and Development Policy, National Institute of Urban Affairs, Centre for Science and Environment, World Resources Institute), tourism/commerce/economic development representatives, EV owners and the broader public.

STEP 2: DEVELOP A VISION AND GOALS

Understanding where EV charging equipment fits within the area, both in the short and longer term, is helpful. The following questions can guide consideration on the current and future role that EVs play in the area:

- How do the goals for EVs align with other goals?
- Will EV drivers use their car for different purposes (i.e. to commute, operate commercially, run local errands, or take long trips, etc.), and do any of these groups of EV drivers align with the government's priority?
- What are the main goals to create charging infrastructure? Easy access to charging for owners, or to reduce greenhouse gas (GHG) emissions?
- What is the timeframe for the plan? What kind of charging equipment deployment (level 2 charging, fast charging) is suitable for the short term (one to five years)?
- What is the long-term vision (five to 20 years)?
- How does the community want to stay informed about progress? How should lessons over time be incorporated back into the planning process?

STEP 3: IDENTIFYING PREFERRED LOCATIONS

A map of the area is essential to this process. Ideally, the map would show the planning boundaries and any existing charging stations, as well as important features shown in Table 1. The table describes the features and identifies the reason why it should be shown on the map. For example, the transportation hub is visible and convenient to locate and is a common destination for many commuters, making it relevant to be shown on the map. For larger areas, it can be helpful to impose a 5 km or denser grid onto the map.

Hainan Case Study – Principles for Charging Infrastructure Planning

Hainan Province in China has developed a set of principles for charging infrastructure location planning for regions with limited data and budgetary resources.[14]

Hainan is an island province of China with 33,920 square kilometers and a population of 9.32 million. It has a seasonal population of 0.8 million due to its mild winters. Hainan has a similar population density (around 300 people per square kilometer) to some Indian states, such as Gujarat and Telangana, and can therefore serve as a reference for charging infrastructure planning.

Hainan recently released its updated charging infrastructure plan for 2019 to 2030. The provincial plan shares some of China's most recent knowledge on planning for charging infrastructure adequacy.

The adequacy goals are based on city tier, vehicle, and location type. The plan categorizes cities into three tiers based on the level of economic development and function (i.e. economic center, tourist destination, or ecological preservation zone). The plan then assigns goals to best suit the city's role and current progress in EV adoption. There are specific requirements for the different location types.

- All residential locations must have, or be ready for the installation of, charging infrastructure by 2020.[15] There should be adequate charging units for every private EV.[16] Slow and shared charging are preferred for home charging availability and accessibility.
- For mid-trip charging there should be two charging or battery switching stations for every petrol/diesel station, usually located every 50 kilometers, on both sides of the road. For island-looping routes, 40 charging or switching stations will be built. Existing gas stations are encouraged to install fast charging equipment.
- For workplace parking, no less than 25 percent of the parking spaces should be reserved for EVs, and workplace charging spaces should be open to the public during off-peak hours.
- Hainan plans to increase from 8,000 public charging units to 51,000 by 2025, and 166,000 units by 2030. It will also increase the number of battery switching stations from 160 to 430 by 2025, and 627 stations by 2030. For private, taxi, and car-sharing EVs, the goal ratio between charging units and vehicles is 1:1. For charging units to buses, city fleets, and commercial vehicles, the ideal ratio is 1:2. In 2019, the ratio is 1:5, and 1:7 if only public charging units are counted.

Table 1 List of Important Features to Show on the Map

Feature	Description	Reasons why it is shown on the map		
		Visible & Convenient	Destinations	Home Charging
Major and minor roads	Highly visible, well-travelled locations	x		
Transportation hubs	Bus depots, shared bike areas, train stations, major intersections, park & ride locations	x	x	
Institutional land uses	Government buildings, hospitals, schools, recreation and community centers and libraries	x	x	
Commercial uses	Retail centers, business districts or tourism destinations, restaurants	x	x	
Gas stations	Sites already popular for “refueling”	x		
Parking facilities	Surface lots, underground or structural parking facilities not covered under other uses	x		
Future growth areas	Especially if significant commercial, institutional, or high-density residential use is planned	x	x	x
Jobs density	Employment centers with large number of jobs		x	
High density residential uses	Areas where residents may not have their own parking (i.e. apartments)			x
Publicly owned properties	Publicly owned facilities that are not covered under institutional uses (including unused properties)		x	
Power lines/stations	Proximity to existing high-power electricity			

Source: NRDC adopting British Columbia Toolkit information

Stakeholders can develop criteria for location selection, as listed in bullets below. Then, stakeholders can rank locations with the criteria to achieve stakeholder goals.

General criteria for good locations include:

- will the siting support commuters, visitors, residents, or business?
- does the siting support an even distribution throughout the area;
- does the siting supports residential and commercial areas with expected future growth;
- does the siting consider the travel pattern and the mode of travel of the commuters;
- roughly how expensive would it be to install chargers?
- is the location easy to see and find;
- is there something to do nearby;
- is the demand for general vehicle parking so high that it creates conflicts for parking space;
- are there potential co-benefits with the siting (i.e. local economic development, green branding, noise reduction);

STEP 4: IDENTIFYING PREFERRED SITES

Identification of preferred sites starts with identifying possible sites at high potential locations. If there is more than one possible site, the options can be evaluated and ranked with a list of criteria in Table 2. In smaller communities, maps and personal knowledge will suffice, or if necessary, a walk through the location. During the planning stage, it is beneficial to clarify ownership (or ownership model) of the possible sites, system operation, and the development of partnerships.

Table 2 List of Criteria for Good Charging Sites

Visible	The site should have maximum visibility for possible users
Secure	The site should be well-lit and visible to others. General environmental design principles on crime prevention can be used here
Near a source of power	Existing light fixtures, power poles etc. can reduce installation costs by eliminating the need to trench through concrete or pavement, thus reducing the amount of renovation required to extend electrical conduits
Level topography	The site should not be on a hill, for rolling risk, and should not be in a depression, which could accumulate rain or snow
Wide availability	Ideally, the site should be available at any time of the day, and at a minimum, during business hours
Easy access and egress	Above ground locations often have more flexibility. There should be ample room to accommodate the number of planned vehicles without obstructions
Sheltered and ventilated	This will greatly improve the charging experience for a safety and comfort perspective
Timing constraints	Identify if anything might make the site quicker (e.g., willing land owner) or slower (e.g., city center power upgrade complications) to deploy charging

Source: NRDC adopting British Columbia Toolkit information

Once the number of possible locations and sites are reduced, a detailed site evaluation should be completed, and a site plan should be prepared. The plan should address, including but not limited to, measurement of the potential site to ensure ability to accommodate planned number of vehicles and charging equipment, and evaluation of electrical conduits near the site and measurement of their distance from the site.

2. MODELING APPROACH

Communities with extensive data on traffic patterns and vehicle use, often utilize an approach with extensive modeling. This model-based approach usually requires less local human knowledge in specific areas but requires datasets of considerable size on locations and potential vehicle travel trajectories.

Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

National Renewable Energy Laboratory (NREL) developed the Electric Vehicle Infrastructure Projection Tool (EVI-Pro) in collaboration with the California Energy Commission to estimate regional requirements for charging infrastructure. It uses EV market projections and real-world travel data to estimate future requirements, under various scenarios, for residential, workplace, and public charging. Model outputs include: anticipation of spatial/temporal consumer demand for charging, weekday/weekend travel behavior, and regional differences in travel behavior and vehicle adoption. A user-friendly, simplified version of EVI-Pro is available online.[17]

The use of modeling may work well if the planning area is too big for the planning body to purely rely on local knowledge, and when good data is already available or can be easily collected. It is potentially more transparent as well, particularly if the data inputs and the model are transparent. As planning goes from the regional scale to the local level, additional stakeholder voices and factors may need to be considered, necessitating human knowledge and decisions.

Currently, there are a number of models available, with several applied to the real-world cases. One example is the application of the University of California Davis EV Planning Toolkit to Greater Philadelphia in the United States.[18] The model tells where people may buy EVs and provides the location and magnitude of anticipated charging demand. The locations are not specific but are generally within a one to two-mile area. A literature review on different types of models is available in the Appendix.

EV Infrastructure Location Identification Tool (ILIT)

The EV Infrastructure Location Identification Tool (ILIT) was developed by M.J. Bradley & Associates and the Georgetown Climate Center, to support North Carolina, and other states in the Northeast and the Mid-Atlantic region. The tool generates direct-current (DC) fast charging development suitability rankings for exits along designated highway corridors in the region. The tool also offers assistance for future charging infrastructure development planning. The model is free online.[19]

3. HYBRID APPROACH

A hybrid approach is when both stakeholder participation and technical modeling with limited available data is applied in the planning. Modeling results are usually applied to transform sizable data into human-interpretable siting suggestions for the area, and then local knowledge is used to verify and refine the siting solution from the model, while taking into account stakeholder inputs and site-specific factors.

An advantage of the hybrid approach is that it makes initial planning for bigger areas more manageable by employing a small group of modelers, rather than a large gathering of stakeholders. In the later phase before implementation, stakeholder engagement and local knowledge will still be needed to fill in the gaps between the modeling results and reality.

The City of Columbus, Ohio in the United States successfully used the hybrid approach in planning their charging infrastructure locations.[20] In Columbus, officials used the model EVI-Pro developed by the National Renewable Energy Laboratory (NREL) with available data combined with a series of stakeholder meetings for identifying locations and siting for charging infrastructure.

Smart Columbus[21]

Smart Columbus is an initiative for the Columbus Region. Columbus, Ohio competed against 77 other US cities to win the Smart City Challenge in 2016.[22] With this initiative, Columbus is transforming its transportation system and aggressively growing the electric vehicle market. One of the many projects underway is the expansion of EV charging stations, and to date, 1,068 charging ports have been installed.[23] More information can be found in the playbook published on the Smart Columbus website.[24]

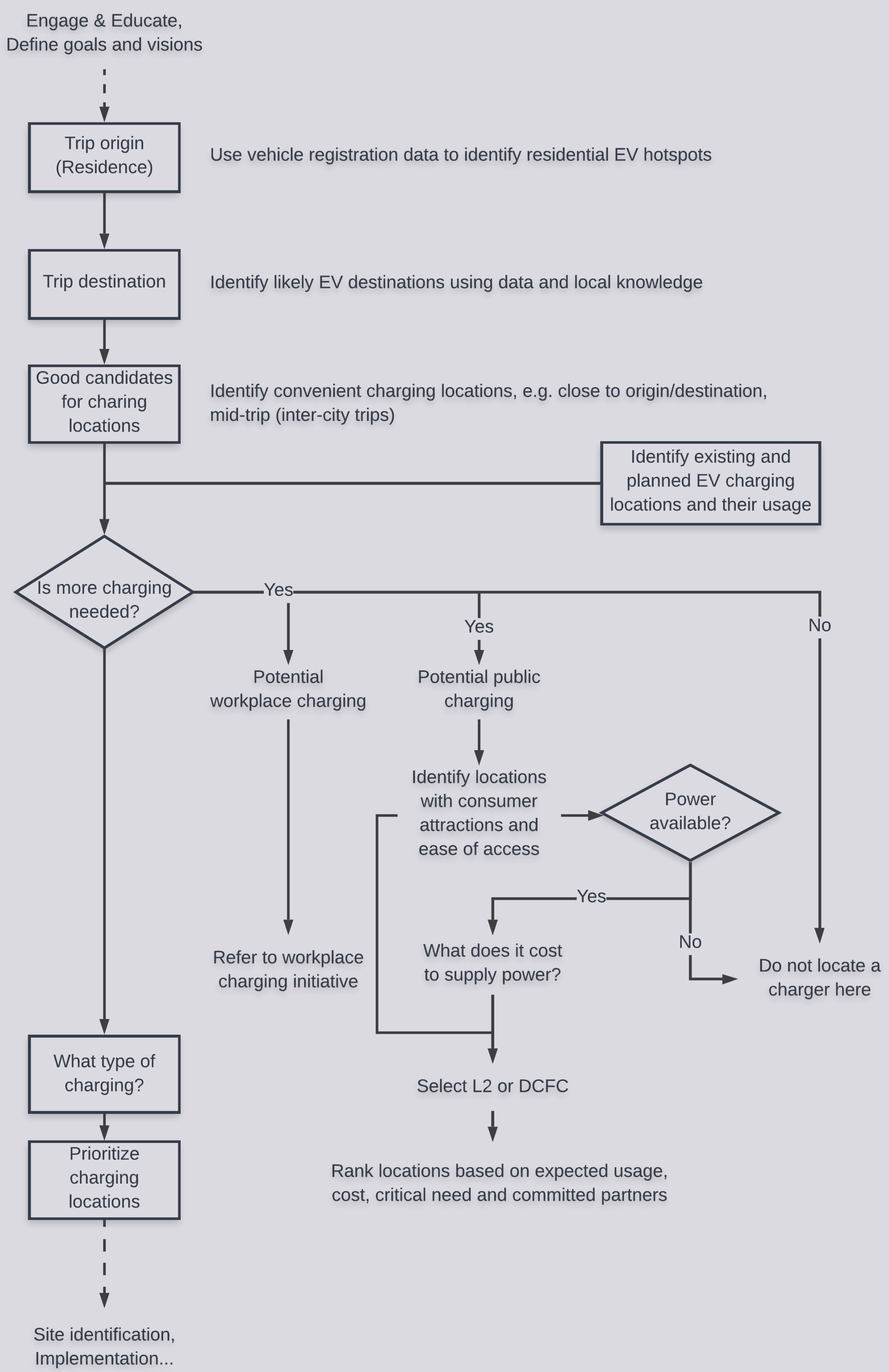
To determine charging locations for the city, officials considered data from the seven contiguous counties to account for commuters and traffic patterns. The flow chart in Figure 1 shows the process of planning charging stations. For the planning process, officials first modeled to identify potential locations based on available data. The officials then used the framework presented in the “Local Knowledge” Stakeholder approach, described above, to decide the more specific location and siting areas based on the initial locations identified through the modeling exercise. In other words, given the stakeholder’s knowledge of location specific uses, the stakeholder process is used to refine from the modeling to maximize practicality and use for siting and locations for charging infrastructure.

The City of Columbus’ approach, as described in the Box, illustrates the hybrid approach. First, Columbus used EV registration data to determine EV travel origins. Anonymous GPS travel data that originated from the EV travel origins, acquired from third parties, were used as inputs for EVI-Pro model. The model simulates EV travels based on the inputs and delivers results on how many charging units are needed for different purposes. The results are processed to identify 300 hot spots that indicate future demand for non-residential L2 charging. These hot spots, represented on the map as 500-meter-diameter bubbles, are where EVs were simulated to be frequently parked for long durations at low battery “state of charge” (SOC) levels. These bubbles, coupled with data such as parking meter collection data, can give the initial candidate locations for charging stations.

Workshop and stakeholder meetings were then conducted to put in local knowledge to finalize the locations and siting. The planning process took roughly six months, of which the initial data processing consumed a significant amount of the time.

IMAGE CREDITS: CHARU LATA, NRDC

Figure 1 Process Flow of Charging Infrastructure Location/Site Identification for Smart Columbus.



Source: NRDC adopting Smart Columbus information

CONCLUSIONS AND RECOMMENDATIONS

Planning for public charging infrastructure is essentially answering *where* and *how many* of *what type* of chargers should be placed in the planning area. This factsheet focuses on the *where* perspective. We present three approaches that can be used for EV location and site selection: local-knowledge stakeholder, modeling, and hybrid.

Leveraging local knowledge in the stakeholder approach works for small-scale planning. However, for larger-scale regional or city-wide planning, models can be used to process available data into initial location recommendations, reducing the human resources needed.

For planning in big cities or regions in India (mainly the million plus cities as per 2011 census or the smart cities notified by Ministry of Housing and Urban Affairs), the hybrid approach of modeling and local knowledge may work best. An initial modeling phase will help deliver a data-based, transparent selection of possible locations. Seeking potential collaborations with research institutions and data collectors, such as Google may greatly accelerate the modeling work. Later, stakeholder engagement and human decisions will ensure the selections are viable in the real world, and that sites are selected with holistic engineering, economic, and policy considerations.

IMAGE CREDITS: CHARU LATA, NRDC

APPENDIX 1: SAMPLE MATERIALS FOR LOCAL KNOWLEDGE APPROACH WORKSHOP

(Source: British Columbia Tool Kit[25])

A. LIST OF MATERIALS FOR PLANNING WORKSHOP

1. List of stakeholders
2. Agenda
3. Location and site exercise
4. Location criteria rating sheet
5. Rating sheet for proposed locations
6. Rating sheet for preferred sites
7. A map or maps showing: Planning boundaries, existing EV charging stations, major or minor roads, transportation hubs, institutional land used, commercial uses, gas stations, parking facilities, future growth areas, jobs density, high density residential areas, publicly owned properties, aerial photograph or satellite imagery, and five-kilometer grid for larger area planning
8. Presentation material

B. LIST OF STAKEHOLDERS

1. Government in the planning area
2. Business owners in the area
3. Land developers and owners
4. Utility
5. Institutions
6. Tourism, chamber of commerce and economic development representatives
7. EV owners
8. General public
9. Adjoining regional districts

C. WORKSHOP AGENDA TEMPLATE

1. Welcome and introductions (15-30 mins)
2. Learning from others (30-60 min)
3. Government and utility perspectives (30 mins)
4. Opportunities and challenges (30 mins)
5. Plan vision and goals (30 mins)
6. Review location criteria (15-30 mins)
7. Review roles and responsibilities of the government, residents, businesses and institutions (30 mins)
8. Charging station location exercise (60-90 mins)
9. Rating and ranking of proposed locations against criteria, vision and goals (30-60 mins)
10. Identification of possible sites for top rated locations (30-60 mins)
11. Summary and next steps (15 mins)

D. LOCATION AND SITE CRITERIA WORKSHEET

Workshop attendants can take around an hour to consider possible charging station locations. The goal is that each one can identify 8-10 possible charging station locations for detailed technical evaluation. Table below, as an example, can be used to note thoughts on possible locations, their role in the area and site-level information. At this stage, site-level information needs not to be complete.

	Location Role in Area							Site-level Criteria						
Possible Location	Community centers/Destination	Major employment center	Major retail center	Highly Visible (Intersection, Major road, etc.)	High density residential area	Future Growth Area	Publicly owned site	Source of power nearby	Secure, well-lit, visible	Not on hill	Available 24 hours	Above ground	Easy access and egress	Sheltered and ventilated
Example: Library	Yes	No	No	No	No	No	Yes	Maybe	Mostly	Yes	Yes	Yes	Yes	Mostly
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

E. RANKING SHEET OF LOCATIONAL CRITERIA

This table helps planners to define short term and long-term goals. Ratings can be assigned as, for example, very important (3), important (2), and less important (1).

Criteria	Short term	Long term
Easy to see and find		
Something else to do nearby		
Supporting:	-	-
Commuters		
Visitors		
Residents		
Businesses		
Institutions		
Co-benefits:	-	-
Local economic development		
Green branding		
Other		
Avoidance of conflicts for parking		
Even distribution throughout		
Emphasis on future growth areas		

F. RATING OF POSSIBLE LOCATIONS/SITES

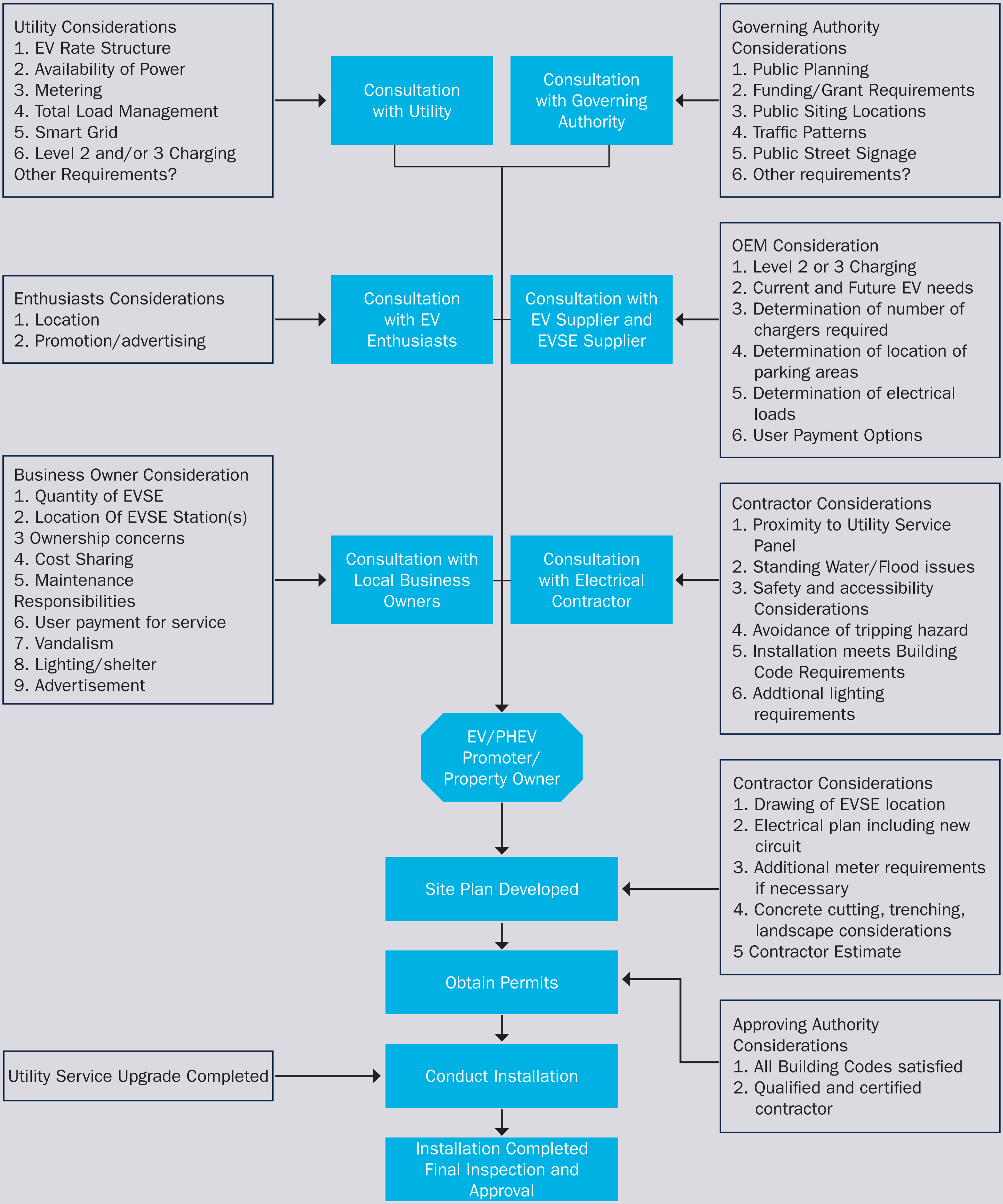
Locations and sites can be ranked to refine initial selections down to desired numbers. They can be rated simply with, very promising (3), promising (2), and less promising (1). It is also possible to use more complex rating method directly taking into account the individual criteria.

Location No.	Possible location/ address	Rating
1.		

Site No.	Possible site	Rating
1.		

IMAGE CREDITS: CHARU LATA, NRDC

G. INSTALLATION FLOWCHART FOR PUBLIC CHARGING



APPENDIX 2: LITERATURE REVIEW OF MODELS FOR IDENTIFYING CHARING INFRASTRUCTURE LOCATIONS AND SITES[26]

PLANNING OF CHARGING INFRASTRUCTURE

From the perspective of *what is being considered in planning*, research has been done with different types of charging facilities, types of vehicles, scale of planning, data sources, and constraints.[27]

1. MODES OF CHARGING

While the most commonly treated case is normal/ slow charging stations, there are many articles on new/ alternative technologies. Some studies consider fast charging.[28] Battery switching stations are considered in some.[29] Some consider non-traditional types such as mobile charging (Yang et al., 2012) and mobile switching (Huang et al., 2014) stations.[30] In some, mixed types of charging facilities are taken into consideration altogether.[31]

2. TYPES OF VEHICLE

Usually planning studies are targeted for private EV drivers, but we can also see solutions proposed for company fleet vehicles (Yang and Sun, 2015), taxis (Ko and Shim, 2016), buses (Zheng et al., 2013), and scooters (Wang and Lin, 2013).[32]

3. SCALE OF PLANNING

There are some theoretical studies that only demonstrate the feasibility of the proposed method with artificial examples.[33] Most studies use real data from areas of different sizes, such as parts of cities (Sadeghi-Barzani et al., 2014), cities (Bernardo et al., 2016), regions (Mak et al, 2013), islands (Wang, 2007), and states (Chung and Changhyun, 2015).[34]

4. DATA INPUTS USED

Different methods vary in the aspects that are considered for determining suitable locations for charging stations. Most models include the user's demand for EV charging. However, many different indicators are used to quantify and locate this demand. Data is used, often in combination, in studies, including demographic data (Namdeo et al., 2014; Koyanagi et al., 2001), building data (Namdeo et al., 2014), vehicle registration data (Koyanagi et al., 2006), proximity to major transit connections (Koyanagi and Yokoyama, 2010), traffic data (McPherson et al., 2011; Bernardo et al., 2016), and parking data (Capelle, 2010).[35]

5. CONSTRAINTS

Besides meeting the demand for charging, other factors are also taken into account, and can affect the outcome. For example, the impacts on the electricity distribution grid from planned charging infrastructure (Phonrattanasak and Leeprechanon, 2012; Jamian et al., 2014; Sadeghi-Barzani et al., 2014), and the economic feasibility from costs of connection, construction and operation can all be constraining factors (Wang, 2007; Mak et al., 2013; Tang et al., 2013).[36]

METHODOLOGICAL APPROACHES

From the perspective of *methodological approaches*, studies use different ways of modeling spatial entities, look for discrete or continuous location choices, vary in level of formalism, and use different mathematical tools.

1. MODELING OF SPATIAL ENTITIES

It is common to model demand and supply in the form of points.[37] Studies suggest that areas can be represented either unevenly sized (Namdeo et al., 2015) or with a raster (Koyanagi et al.,2006), or at the cost of information loss, transformed into points by using the centroids of the areas (Tang et al. 2013).[38] For road networks, it is common to use graphs.[39]

2. DISCRETE OR CONTINUOUS LOCATION CHOICES

In a discrete case, the potential locations for charging stations are predefined. Usually existing infrastructure locations such as cities within a road network (Wang and Wang, 2010), road junctions/intersections (Bernardo et al., 2016), parking lots, or gasoline stations (Wang et al., 2010) are used as candidate locations.[40] In the continuous case, EV charging stations can be located anywhere within the given area.[41]

3. LEVEL OF FORMALISM

Charging infrastructure siting can be done pragmatically with local knowledge and informal ad-hoc approaches, and leave space for intuitive decisions. More formally, decisions can be loosely based on overlay analysis of geographic data. Mathematically formalized methods predominate scientific literature. Location choice is commonly formulated as an optimization problem.

4. MODELING APPROACHES

When formulated as a (mixed) integer linear problem, concepts such as the p-median problem (Ko and Shim, 2016), p-center problem (Jia et al., 2014), set covering (Wang and Wang, 2010), and flow refueling location model (Kuby and Lim, 2005) can be used.[42]

Heuristic approaches that have been applied to the location planning of EV charging infrastructure include particle swarm algorithms (Tang et al., 2013), genetic algorithms (Sadeghi-Barzani et al., 2014), bee colony algorithms (Jamian et al., 2014), ant colony optimization (Phonrattanasak and Leeprechanon, 2012), or greedy algorithms which sequentially decide the next optimal location (McPherson et al., 2011; Wagner et al., 2014).[43]

Another approach to finding good locations is to perform a spatial cluster analysis of data representing the demand for charging.[44] A further possibility is to model location choice within the framework of game theory, where a good combination of locations corresponds to a game theoretic equilibrium.[45]

Several authors have implemented simulations of EV mobility and charging which allowed them to also analyze locations of charging infrastructure. Existing traffic models have been extended (Hess et al., 2012; Gonzalez et al., 2014; Hiwatari et al., 2014) and new agent-based models have been implemented (Sweda and Klabjan, 2011; ElBanhawy et al., 2014).[46] The advantage of using simulation is that it allows to model the diverse aspects that determine individual EV drivers' need for charging in more detail. Instead of using static land use data or single trip data, trip chains can be modeled. Such simulation models can serve to identify areas of high charging demand (Gonzalez et al., 2014; Hiwatari et al., 2014; ElBanhawy et al., 2014) or evaluate given alternative charging infrastructure layouts (Sweda and Klabjan, 2011; Hoerstebrock and Hahn, 2014).[47] Going a step further, in a simulation-optimization approach, the location plan is repeatedly changed and the simulation reperformed, in order to find an optimal layout.[48]

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ENDNOTES

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HIGHLIGHTED REPORTS

Air pollution in Pune: Research and Evidence for Developing the Pune Air Information & Respond (AIR) Plan.

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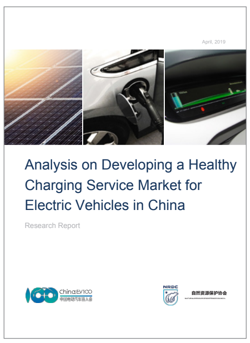
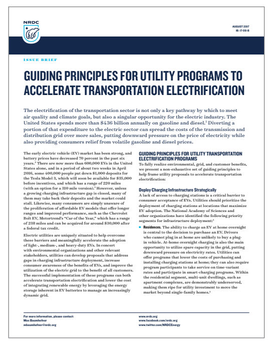


CHINA: Analysis on Developing a Healthy Charging Service Market for Electric Vehicles in China



US: Guiding Principles for Utility Programs to Accelerate Transportation Electrification

HIGHLIGHTED BLOGS

- **Advancing EV Charging in Key Indian States,** Charu Lata and Anjali Jaiswal, December 2019, https://www.nrdc.org/experts/anjali-jaiswal/advancing-ev-charging-key-indian-states
- **India Focus: Telangana Moves on Electric Mobility,** Anjali Jaiswal, Charu Lata and Shabib Ansari, September 2019, https://www.nrdc.org/experts/anjali-jaiswal/india-focus-telangana-moves-electric-mobility
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