The Business Case for Sustainable Infrastructure

Energy Infrastructure

The Infrastructure for Electric Vehicles *Background Note*

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ABSTRACT

The Business Case (BC) of EV infrastructure is analyzed in this report based on literature material. EV adoption is considered by definition sustainable and the accompanying case studies will focus on the deployment of EV infrastructure in different contexts, so that it can be done at the lowest possible cost and with the greatest possible benefit. More specifically this Background Note (BN) presents:
- the variables that affect the development of a BC for Electric Vehicles infrastructure
- the infrastructure deployment considerations, and
- the barriers of investing.

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1 VARIABLES THAT AFFECT THE BUSINESS CASE FOR THE INFRASTRUCTURE OF ELECTRIC VEHICLES

1.1 A new technology needs a new approach

Electric Vehicles educe GHG emissions in urban regions and can slow down climate change by displacing the demand for hydrocarbons with electric energy, with a large percentage supplied from renewable sources. Environmental policies and sustainability objectives of Governments and the private sector drive the interest in adopting Electric Vehicles for fleets as well as by single users. Yet there are open questions about the charging infrastructure and the policy to pave the way for vehicles electrification. Questions on the operation of charging stations, including the power of the charging ports, the number of ports at a site, the available grid power at that site, and customer demand.

A multi-level systems approach is critical to understanding the opportunities and challenges. The approach should evaluate energy impacts, identify the levers that will improve energy productivity and enable energy efficiency, develop a framework that will estimate the potential of electric vehicles and their economic & environmental benefits, and finally support the users and local/regional transportation systems.

1.2 Understanding the market

Today, users of electric vehicles demand lower prices, a longer driving range and fast charging stations. Taking these under consideration, and with the support of policymakers, automakers need produce third generation electric vehicles and at the same time drive costs down to make them competitive and profitable, even if oil prices remain low. With electric vehicle costs steadily falling, the transition becomes feasible. This potential is enabled by the ubiquity of electricity and the growing availability of low-carbon, renewable energy sources. Additionally, new infrastructure business models are being adopted raising consumer awareness, capturing indirect costs of charging, and engaging electric utilities.

"Growth in the electric vehicle market requires many actions by many players. Actions by many policy and industry stakeholders are key to reducing consumer barriers related to electric vehicle uptake with supporting policy, incentives, infrastructure, and consumer awareness. States develop policy and implement incentive programs, whereas cities focus more on local policies and nonfinancial consumer programs, and utilities increasingly are engaged in infrastructure deployment and consumer education."[1]

The changing landscape of vehicle ownership and use has also implications on sales and electricity demand. Social and demographic changes affect how much people drive electric cars and the demand for new vehicles. Households own fewer vehicles per household, the vehicle purchase process has become longer due to extensive research of the available options of vehicles, the use of public transportation modes is increasing, and alternative methods such as car sharing or on-demand transport services are leading to the "transportation-as-a-service (TAAS)" business model with potential projected savings four to ten times per mile than buying a new car".[2]

[1] "Expanding The Electric Vehicle Market In U.S. Cities". ICCT, 2017. p. 30.
[2] "Utilities and Electric Vehicles. Evolving To Unlock Grid Value". Smart Electric Power Alliance (SEPA). March 2018. p. 12.

1.3 Incentives

Financial and nonfinancial incentives help overcome key cost and convenience barriers and give impetus to the early electric vehicle market while technology costs decrease and awareness improves. "Actions by governments, utilities, and the industry are leading to a substantial increase in the size of the charging infrastructure network. Government support includes direct deployment, financial incentives for residential or commercial infrastructure, expediting of permitting and installation processes, and adoption of electric vehicle–ready building codes. Similarly, utility actions include direct installation as well as financial incentives for residential and commercial charging stations. Multiple automakers (such as BMW, Nissan, Tesla, and Volkswagen) and partner equipment providers are also investing in charging infrastructure to support greater adoption of EVs."[3]

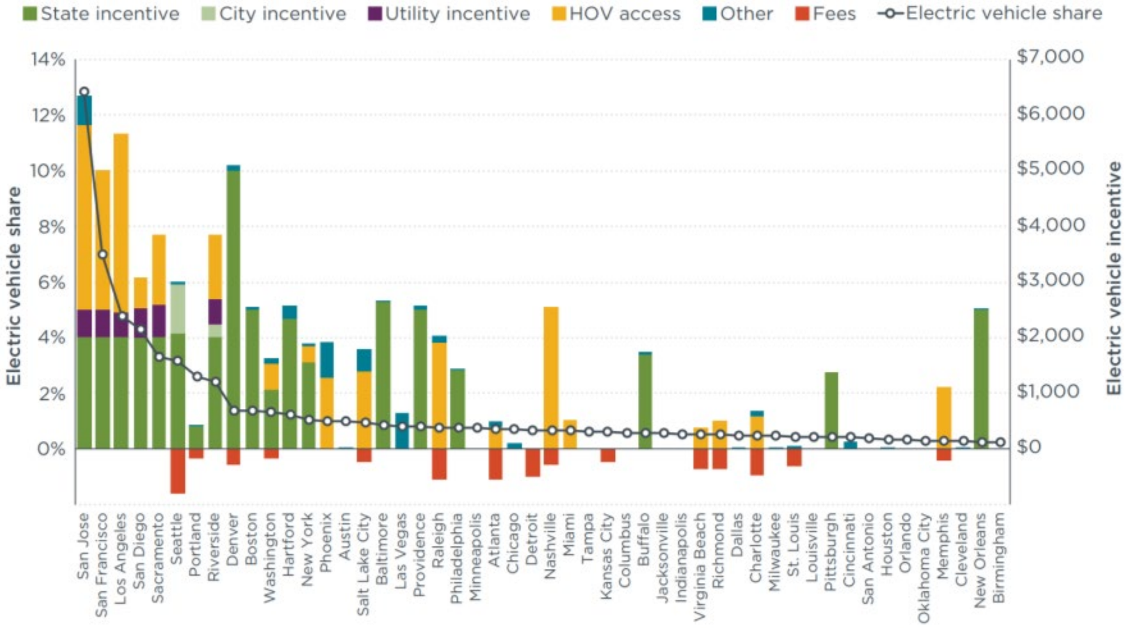

Fig.1: *EV share of new vehicles and available consumer incentives in major U.S. metro areas. (New vehicle registration data from IHS Automotive) (ICCT, 2018)*

Overall, the experience worldwide demonstrates that substantial financial incentives are effective at motivating consumers to adopt EVs. The many state incentives differ in monetary value, restrictions, and calculation methods and make it challenging to educate consumers on the incentives that are available to them and emphasize the need for a clear, up-to-date source of information for consumers. Consumer incentives are related to EV purchase and operation, parking and high-occupancy vehicle lane access.

[3] "Expanding The Electric Vehicle Market In U.S. Cities". ICCT, 2017. p.6.

2 CONSIDERATIONS FOR DEPLOYING THE CHARGING INFRASTRUCTURE

The successful deployment of EVs involves many entities and requires the resolution of complex issues. Despite the EV improvements, charging infrastructure still suffers from fragmentation, inconsistent data availability, and a lack of consistent standards in most markets. The lack of charging infrastructure presents a barrier to the EV market. Today, governments, auto industry experts, researchers, individuals, utility companies and the private sector in general, have unanswered questions related to the charging infrastructure. How much is required for a mature market and what types are likely to need in the future as technology continues to evolve? Which policy frameworks and funding mechanisms could help to ensure that the necessary charging infrastructure is deployed? Finally, are there global examples of policies and initiatives that demonstrate how best to overcome prevailing barriers and deploy charging infrastructure? In this part of the report the charging infrastructure topics are analyzed.

2.1 Types of charging

There are three types of EVSE,[4] which are classified by the rate at which vehicle batteries are charged and by their communication capabilities. Charging times vary based on how depleted the battery is, how much energy it holds, the type of battery, and the type of charging equipment.

Charging level	Voltage (V)	Typical power (kW)	Setting
Level 1	120 V AC	1.2-1.8 kW	Primarily residential in North America
Level 2	200-240 V AC	3.6-22 kW	Home, workplace, and public
DC fast	400 V DC	50 kW or more	Public, primarily intercity

V = volt; AC = alternating current; DC = direct current; kW = kilowatt

Fig.2: *Characteristics of Level 1, Level 2, and DCFC (Source: ICCT, 2017)*

L1 is the standard charging equipment that applies in home charging and requires a typical outlet. It can add about 40 miles of range after an 8-hour charging. A L2 charger is used for charging at homes or public stations. It requires a 240V power supply and its charging rate depends on the vehicle's specs and the available power network. After 8 hours of charging a vehicle can drive up to 180 miles. Level 2 is the most common public charger available today in many office buildings, parking garages and shopping centers. DCFC is the fastest recharging method today for public charging. It can add 50-90 miles in 30-min charging time, depending on the station's power capacity and the EV specs. Tesla's supercharger is the fastest that exists today adding up to 170 miles in half an hour.

2.2 Siting

EV integration presents strong synergies with the built environment. Although there are some applicable federal and state permitting processes that affect EV infrastructure deployment (such as federal environmental laws: NEPA) and state regulations, travel distances, trip patterns, and vehicle registration data show that most EV registrations and

[4] EVSE is the equipment used to deliver the appropriate and safe flow of electricity from an electricity source, such as the electricity running to the electrical outlets at your home, to a PEV.

travel will be within urban areas. The usefulness of the vehicles will largely depend on the availability of charging infrastructure, whether at home, at work, or in public locations.

Ensuring that the charging network operates efficiently and meets driver expectations, is crucial in maintaining future investment and support. One critical step toward maximizing the return on investment is to place charging stations in optimal locations at a local level to maximize usage, avoid traffic and parking issues, and minimize stress on the power grid. Chargers can be installed at home, at work, in public, and on highways for long-distance trips. Combined home, work, and long-distance charging could in theory cover an EV owner's entire energy demand. The energy consumed in houses and workplaces depends on the number of chargers installed and the amount of energy they provide.

Below is a summary of the main siting considerations according to the Rocky Mountain Institute:[5]

- Public charging stations should be sited for high utilization.
- L2 chargers should be sited where drivers have a preference to charge over a longer interval (i.e., several hours), such as workplaces and residences.
- DCFC should be sited where utilization will be high and their grid impact will be low.
- Hubs that provide a combination of L2 chargers and DCFC are likely to be the best way to serve public fleets, transportation network carriers, and autonomous vehicles.

2.2.1 Home charging

Home charging depends on whether the EV owners have a garages and on income demographics, whereas charging penetration at work reflects the employers choice or regulatory requirements. Most EV drivers charge their vehicles overnight at home using L1 or L2 charging equipment. Residential equipment is frequently installed in garages, but outdoor installation and use are also safe. Charging at a multi-family residential complex requires additional considerations and may be more similar to public charging than to charging at a single-family home.

2.2.2 Public charging

Although the majority of EV owners charge at single-family homes, public charging is an important part of the electric vehicle ecosystem as it can increase the daily useful range of EVs and reduce the consumed hydrocarbon fuel. Public charging stations must be deployed and integrated with consideration for daily commutes and typical driving habits. Without having a universal benchmark for the ratio of EVs/charging station, it varies across markets depending on vehicle uptake and housing and population density. Public charging points should typically be located where vehicle owners are highly concentrated and parked for long periods of time, such as shopping centers, airports, hotels, government offices, and other businesses.

Fleets that choose to incorporate EVs into their operations must account for several factors when planning for charging stations. Peak demand, duty and cycles, garaging locations, vehicle models, and availability of off-site public charging stations can all factor into decisions about the number, location, and types of charging units. City planners, fleet managers, utilities and installers should jointly determine the best locations.

[5] "From Gas to Grid. Building charging infrastructure to power electric vehicle demand", Rocky Mountain Institute, 2017. p. 37.

2.3 The right mix

"Charging infrastructure availability varies dramatically at a local level, and there is no universal benchmark for the amount of charging infrastructure required. Although national-level numbers of charge points allow easy comparisons across markets, these statistics hide the high level of variation among regions and cities within a single country. Moreover, characteristics such as the balance between regular and fast charging can also vary widely within a single country."[6]

As charging infrastructure continues to expand, a key issue is in establishing the correct balance between convenient-yet-expensive DCFC and inexpensive-but-slower L2 charging. The right mix of chargers, or which mix is best, will vary from place to place and over time, as vehicle technology advances. For example, a widely available public charging network will require a mix of L2 and DCFC, and so deployment plans should include both. According to the following table from ICCT 2018 report, the U.S. public charging infrastructure is 86% L2 and 14% DCFC, whereas the U.S. workplace charging infrastructure is 88% L2, and the rest is a mix of DCFC and L1.

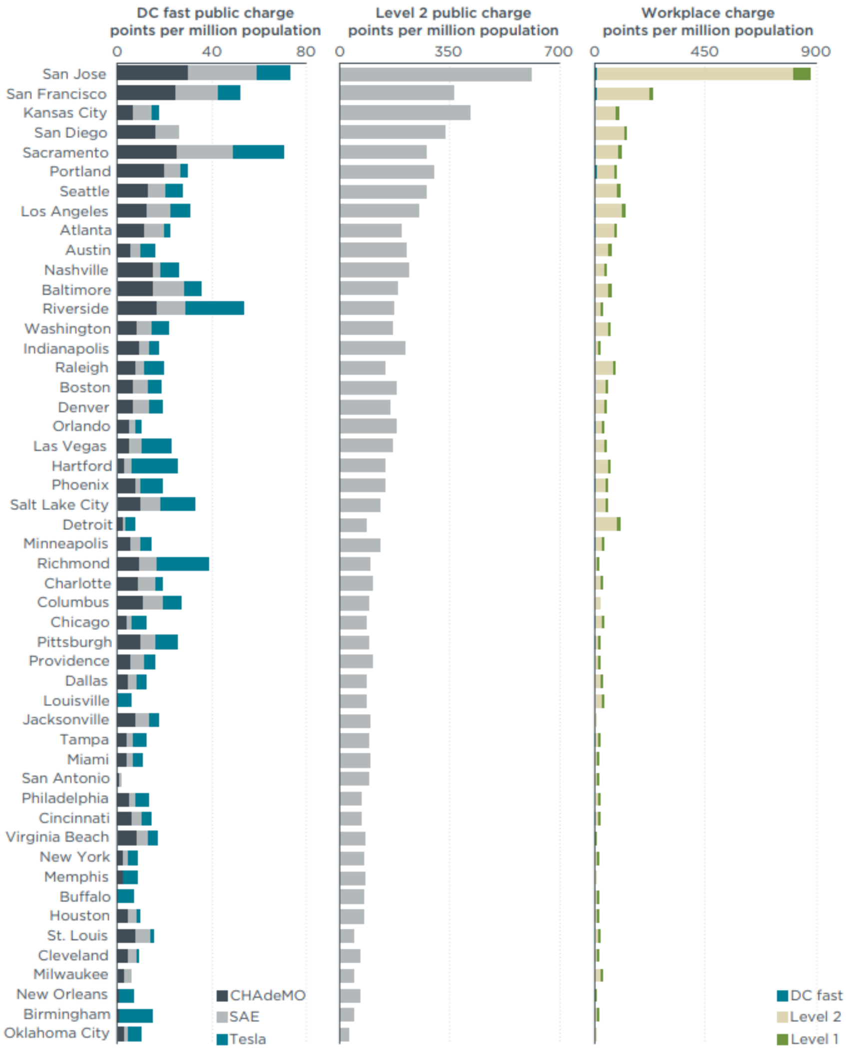

Fig.3: *Public DCFC & L2 and workplace charge points/million population in 50 major U.S. metro areas. Charging infrastructure data from PlugShare.(Source: ICCT,2018)*

[6] "Emerging Best Practices For Electric Vehicle Charging Infrastructure". ICCT, 2017.

2.4 Tariffs

Utilities should set the tariffs for EV charging before significant numbers of EVs appear on their grids, to avoid developing expectations, which will be hard to break.[7] "With EVs now set to arrive in significant numbers, it is critical that utilities and regulators ensure that they have tariffs ready that will guide charging based on system load profiles and off the peaks. Field experience to date, indicates that the optimal tariffs for EV charging employ a time-of-use (TOU) design, and are usually dedicated to EV charging only, because these tariffs offer the maximum opportunity to shift charging to the off-peak periods and provide the greatest grid benefit and the lowest cost of charging."[8] In some cities, especially in California, TOU rates are essential for saving money on fuel costs. A TOU electric rate plan, for example in Oakland, CA, recharging only costs the equivalent of $1.03/gallon whereas using the standard electricity plan is equal to buying gasoline at $3.34/gallon.[9]

According to the Rocky Mountain Institute best practices for charging tariffs include:[10]

- The creation of dedicated tariffs for EV chargers because their demands will be different from that of a household or business and can be controlled separately and with more flexibility.
- The different tariffs requirement for slow and fast chargers to optimize utilization, charging station economics and grid impacts.
- The necessity of some level of time-variance or dynamic pricing for all EV tariffs, in order to optimize charging patterns for grid services and reduced grid impacts.
- DCFC chargers being on tariffs with reduced, delayed, or no demand charges until the market matures and utilization rates are high enough that demand charges constitute a normal portion of monthly bills (30%).
- The consideration of creating specific tariffs for DCFC to promote a strong and sustainable business case for owning and operating them.

2.5 Integration of the Electricity Grid

Transportation and Energy Infrastructure Systems have strong linkages and interdependencies particularly in the case of EV adoption. A key component of the ecosystem of the EV is the utility, which provides the electricity. Potential barriers can come from the distribution, transmission and generation components as well as the overall system control and the economic structure of electric utilities. [11]

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[7] A key finding of an EV tariff pricing study conducted for San Diego Gas & Electric. Source: Long-Term Electric Vehicle Outlook 2017, Bloomberg New Energy Finance, July 6, 2017. https://www.bnef.com/core/insights/16639/view

[8] "From Gas to Grid. Building charging infrastructure to power electric vehicle demand", Rocky Mountain Institute, 2017. p. 42.

[9] https://www.ucsusa.org/clean-vehicles/electric-vehicles/car-charging-time-type-cost#.XBpaQFZMSHs

[10] "From Gas to Grid. Building charging infrastructure to power electric vehicle demand", Rocky Mountain Institute, 2017. p. 42

[11] According to NREL and LBNL main VGI issues include:
- Long term EV deployment effects on distribution grids
- Business models for utilities to install or support EV chargers
- EVSE demand: side management, charging controls, balancing charging times to avoid peak demands
- Grid storage and load-shifting from EVs
- EVSE network communication, coordination and compatibility
- Interactions between renewable energy generation and EV charging activities
- Impact of demand charges on EVSE charging costs and adoption
- Cyber security issues with EVSE
- Regulation of private utilities or management of public utilities and the relationship to EV policies
- How EV charging effects facility – distribution grid integration, including phase balance

The number of EVs on the road is expected to increase.[12] To support this deployment, approximately 4.5 to 5.5 million charging ports would need to be installed by 2025. EEI and IEI estimate that 50,000 to 70,000 charging ports were available in 2017, in public locations and workplaces, not including home charging. Navigant estimates that at the end of 2017, the total number of installed charging ports in the U.S., including home charging, was approximately 475,000.[13]

An increase in charging stations underscores how important it will be for municipal planners, property owners, utilities, and regulators to actively engage now with installers of charging stations to ensure that they are located in such a way that they can be used effectively as grid assets. At the same time, regulators should ensure that they have accurate estimates of the additional demand these chargers will put on utility grids, and that they are employing measures to reduce the overall impact on the cost of service. If these new charging stations are not installed with sufficient forethought about how and when they will be used, they could have numerous negative instead of positive repercussions on the electricity and might not be used frequently enough to enable a profitable business model for charging station operators.

The USDOE identifies the following steps towards VGI:[14]

- Identify vehicle energy consumption levels (including auxiliary energy consumption, i.e., air-conditioning, thermal management, etc.) for given vehicle specifications, drive cycles, constant speed operations, and traffic conditions (speed variations).
- Based on the vehicle energy consumption levels, identify the power requirements and size and design of the charging system specifications for the expected number of electric vehicles.
- Develop an optimization framework for designing the power rating, track length, and placement of the system's components.
- Analyze the grid requirements and the impact on the grid.

2.6 Benefits from EV adoption

"Limited access to efficient charging stations could become a roadblock towards adopting EV, together with a poor driving range and high acquisition and maintenance prices. With more than 350 new, feature-laden EV models to debut by 2025, with ranges that increasingly top 200 miles, these attributes pose less of a hurdle. Instead, if consumers

- How V2G and exporting power from EVs impacts vehicle and battery life
- Environmental impacts of fuel sources on EV emissions
- Long term EV deployment effects on transmission grids
- EV charging infrastructure incentives and deployment on the building and city scale
- Coordination of energy providers
- Cost-benefit analysis of new EV-related technologies (e.g. wireless charging, AVs, smart charging, V2G, etc.)
- Optimal charging profiles

Source: "Vehicle-Grid Integration. A global overview of opportunities and issues". Lawrence Berkeley National Laboratory & NREL. June 2017. p. 4-6.

[12] I.e., 2017 report by the Edison Electric Institute (EEI) and the Institute for Electric Innovation (IEI).

[13] "Utilities and Electric Vehicles. Evolving To Unlock Grid Value". Smart Electric Power Alliance (SEPA). March 2018. p. 13.

[14] USDOE. "Energy Efficient Mobility Systems Report". Vehicles Technology Office (VTO). FY 2017 Annual Progress Report. p.24.

purchase EVs at the expected rates in the next five to ten years, a lack of charging infrastructure could become an obstacle to EV adoption."[15]

2.6.1 Benefits for Users[16]

Benefits for using EVs explain why the demand for EVs and thus charging stations has been growing. Benefits include:

- High fuel economy and low operating cost. EVs are highly efficient with much lower operating costs compared to conventional gasoline or diesel vehicles.
- Flexible fueling. Charging stations are available at home, work, commercial charging stations, other public locations, private fleet facilities or a combination of the above.
- High performance. State-of-the-art highway EVs reach and even exceed the performance of their conventional counterparts.
- Low emissions. EVs typically produce lower levels of GHG, smog-forming emissions and other pollutants harmful to human health.
- Energy security. EVs reduce the dependency on imported oil as almost all U.S. electricity is produced from domestic sources.
- Compliance. EVs fleets comply with federal, state and local transportation policies.

2.6.2 Benefits for Utilities[17]

Utilities can benefit from engaging the EV industry in three major ways:

- Demand for electricity increases. EV infrastructure will increase electricity demand and potentially lower the average cost of electricity/kWh for all consumers. The U.S. utility industry is facing lower demand and increasing competition from third-party electricity providers such as solar energy companies. The transitioning of transportation from oil-based to electricity provides the utility industry with the potential to tap into the transportation sector, the second largest energy consumer in the US economy.
- Grid load balance. EVs can help balance and smooth grid load as a form of distributed energy storage. Energy stored in EVs during off-peak hours (usually midnight to 7am) can be fed back into the grid during the day when electricity demand is high. With proper rate design, EV deployment can also help reduce peak to non-peak usage ratios through influencing customer behaviors.
- Renewables integration. With smart charging mechanisms, EV interfaces can help utilities to integrate more renewables onto the grid. Chargers can be turned on when extra renewables, such as solar, feed into the grid.

2.6.3 Corporate Benefits

"Workplace charging, in particular, can help attract and retain a cutting-edge workforce and demonstrate leadership in adopting advanced technologies. Employers should consult their utility, governing authority, electrical contractor, charging equipment provider, and other stakeholders early in order to identify and discuss potential challenges. Organizations offering workplace charging can benefit from setting clear guidelines in the areas of

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15 McKinsey 2018. "Charging ahead: Electric-vehicle infrastructure demand". Source: https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/charging-ahead-electric-vehicle-infrastructure-demand

16 USDOE. "Plug-In EV Handbook for Public Stations Hosts". p.5.

17 Sustainable Capital Advisors. Molly Wang. "Electric Vehicles: A Cost and Benefit Analysis for Utilities Engaging the Industry". Dec 2015. Source: http://www.sustainablecap.com/featured-news/fact-sheet-administration-announces-68-cities-states-and-businesses-are-working-together-to-increase-access-to-solar-for-all-americans/

administration, registration and liability, sharing, and pricing to help ensure a safe and successful workplace charging experience for all."[18]

Healthcare organizations, colleges and universities, airports and fleets (such as police, taxi companies, fire services, and public transportation) are major employers and community leaders committed to public wellbeing and are often early adopters of best practices and technology trends. These organizations are located in urban and rural areas and are candidates for installing workplace charging stations.

The adoption of PEV charging stations demonstrates corporate leadership by indicating the organization's commitment to sustainability, the environment, and public health. They can offer PEV charging stations to their fleets, staff and visitors helping to promote electric vehicles, reducing their own carbon footprint, and improving local air quality. GHG emissions from commuting employee vehicle are categorized as Scope 3 emissions.[19] PEV charging can help an organization control its Scope 3 emissions, achieve carbon neutrality, and be recognized and awarded under a number of sustainability reporting programs as they improve the quality of life and to the health of employees, patients, and neighbors.

	NREL, 2016	CAL TEC - LOW	CAL TEC - HIGH	MJ BRADLEY - LOW	MJ BRADLEY - HIGH	MJ BRADLEY - NY STATE	CO EV MARKET STUDY	SMUD, 2015	PETERSON, 2010	KEMPTON, 2008	ISO NE, 2014	ISO NE, 2014
GHG BENEFIT	$1,350	$1,033		$611	$1,294			$62				
FUEL SAVINGS	$10,700	$16,528					$11,249					
RATEPAYER BENEFIT		$2,788	$9,607	$744	$1,692							
TOU GENERATION SAVINGS		$764	$878			$477		$414			$995	
TOU PEAK CAPACITY SAVINGS		$661				$216		$738				
V2G REGULATION										$18,744	$3,068	$16,590
V2G ARBITRAGE									$2,186			
PEV OWNER BENEFITS *2030				-$370	$940			$697				
PEV OWNER BENEFITS *2050				$2,100	$3,380							

Fig.4: *Tabulated EV stakeholder benefits based on literature (Source: Rocky Mountain Institute, 2017)*

[18] https://afdc.energy.gov/fuels/electricity_charging_workplace.html

[19] Under the World Resources Institute and World Business Council of Sustainable Development's Greenhouse Gas Protocol which sets the global standard for how to measure, manage, and report GHG emissions. Scope 3 emissions include indirect emissions such as the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned by the reporting entity, outsourced activities, and other upstream and downstream emissions.

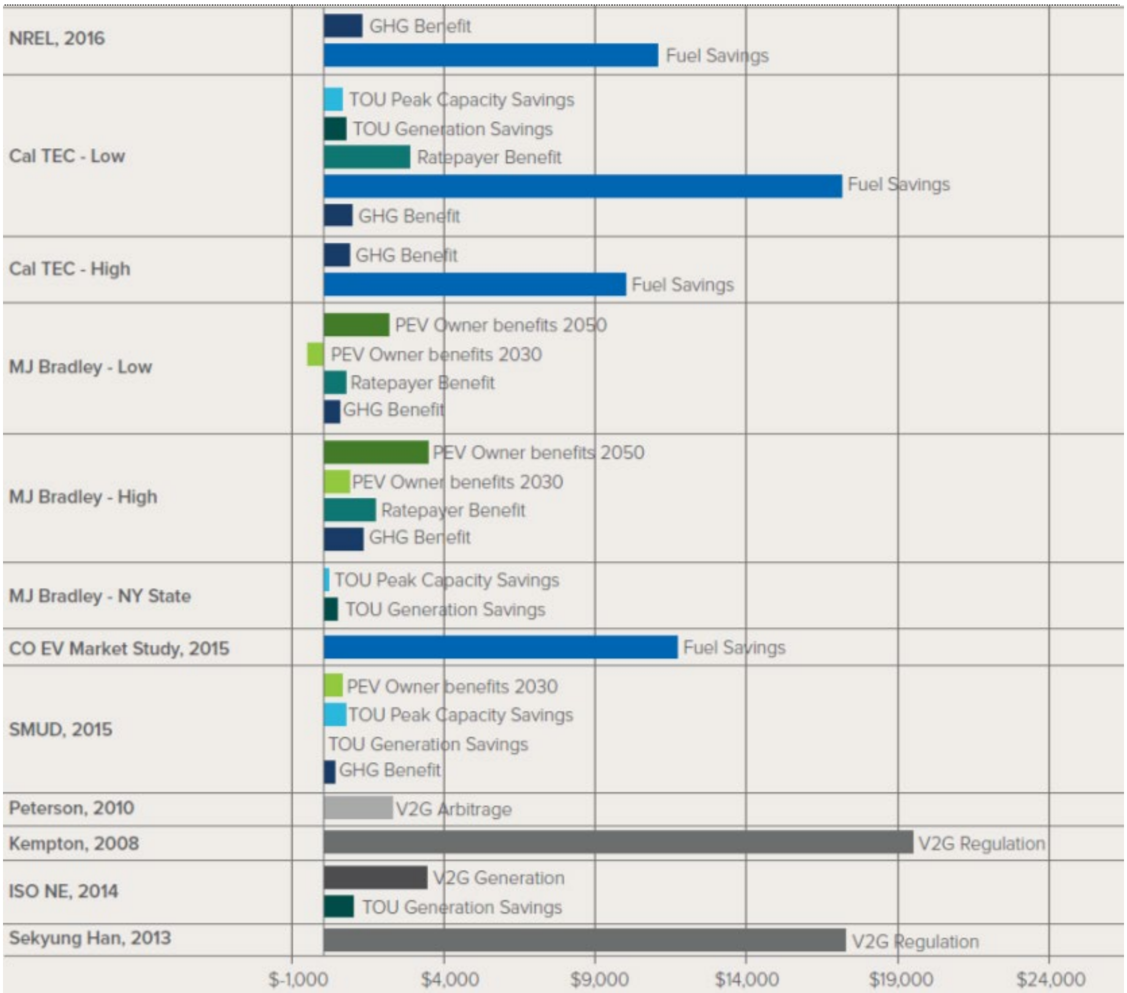

Fig.5: *Detail of stakeholder benefits for EVs based on literature (Source: Rocky Mountain Institute, 2017)*

3 BARRIERS OF INVESTING

3.1 Costs

As every new technology, EV infrastructure deployment is expensive. According to Bloomberg estimates: “the world will need to spend a dizzying $2.7 trillion on charging infrastructure if it's to support 500 million electric vehicles”.[20] Each infrastructure category has different upfront and ongoing investment costs and returns and different entities that would have an incentive to build it.

Although EV charging infrastructure has seen substantial cost declines over the past several years due to new technological innovation and larger production scale, it requires substantial installation costs and possible additional costs for land procurement, administration, and maintenance. Purchasers of charging equipment must consider costs associated with EV capital costs (purchase and installation) and operating costs (maintenance and electricity).

3.1.1 Capital/Construction costs

EVs have a higher upfront capital cost because of different designs and the deployment of a supporting infrastructure. In fleets, this cost may be offset through reduced fuel and maintenance expenses over their lifecycle.[21] Charging infrastructure though has long been a major barrier to EVs. Cost-effective fueling infrastructure is needed to support energy efficient mobility applications.

The capital costs of installing charging infrastructure can vary widely, reflecting on the region, the site and the charger specifications. Installers, in an effort to reduce cost, select less expensive chargers, choose sites strategically and plan for charging infrastructure in new construction.

3.1.2 Operation & Maintenance Costs

The operation of charging infrastructure includes the cost of electricity, with the rate determined by the operators’ business type, the operators’ current and future electricity consumption and required capacity. For EV and PHEV charging, the stability and planning benefits of household electricity rates offer an attractive alternative compared to oil-based transportation.”[22]

“The fuel efficiency of an all-electric vehicle may be measured in kilowatt-hours (kWh) per 100 miles. The cost/mile of an all-electric vehicle depends on the cost of electricity (in dollars per kWh) and the efficiency of the vehicle (how much electricity is used to travel 100 miles). If electricity costs $0.11/kWh and the vehicle consumes 34 kWh to travel 100 miles, the cost/mile is about $0.04. If electricity costs $0.11/ kilowatt-hour, charging an all-electric vehicle with a 70-mile range (assuming a fully depleted 24 kWh battery) will cost about

[20] https://www.technologyreview.com/the-download/609101/charging-infrastructure-is-a-27-trillion-barrier-to-electric-cars/

[21] *“Because vehicles in public or commercial fleet service often log more hours and mileage than personally owned vehicles, and because fleet managers have the motivation and capacity to measure the use of the vehicles within their operations, it is expected that the return on the investment in electric vehicle technology will be more economically attractive for use in fleets.”* Source: “Business Case for Electric Vehicle Use in Service Vehicle Fleets”. Final Report On Project Evan (Electric Vehicle Analysis). June 2013. Pollution Probe.

[22] https://afdc.energy.gov/fuels/electricity_charging_home.html

$2.64 to reach a full charge. This cost is about the same as operating an average central air conditioner for about 6 hours.[23]

3.1.3 DCFC Infrastructure

"Current DCFC infrastructure is known to be expensive to install and operate, especially for sites which see low utilization. It is generally accepted that higher power fast charging will bring with it even higher costs. In the coming years, it is expected that EVs will see increased market penetration, especially in the shared-mobility space. For many drivers who travel a large number of miles, like drivers for shared-mobility fleets, the use of DCFC infrastructure will be necessary. To meet the needs of more customers, many EV models are being offered with larger batteries and greater driving range. Utilizing current fast charging infrastructure, a vehicle with a larger battery will require a longer charge time. For this reason, manufacturers of EVs and DCFCs plan to develop products capable of higher power charging."[24]

- Key Cost Drivers Compared to Residential Charging
  - Can require trenching, extensive wiring, or pavement replacement
  - Must comply with regulations to serve public
  - Often requires charging network access
  - Must be designed and manufactured to withstand significant wear and tear
- DC Fast Charging Costs
  - Electric panel upgrades
  - Host-site identification, analysis, and screening
  - Legal and permitting costs
  - Electric utility interconnection fee

DC Fast Charging Project	Installation Cost per Station
Washington West Coast Electric Highway	$49,000 to $61,500
EV Project (average)	$20,848
EV Project (median)	$20,188
EV Project (highest)	Over $45,000
Orlando Utilities Commission	$6,939 to $8,928

Source: Idaho National Laboratory and Washington State Department of Transportation, Orlando Utilities Commission, 2014.

Fig.6: *Public charging costs (Idaho National Lab, 2014)*

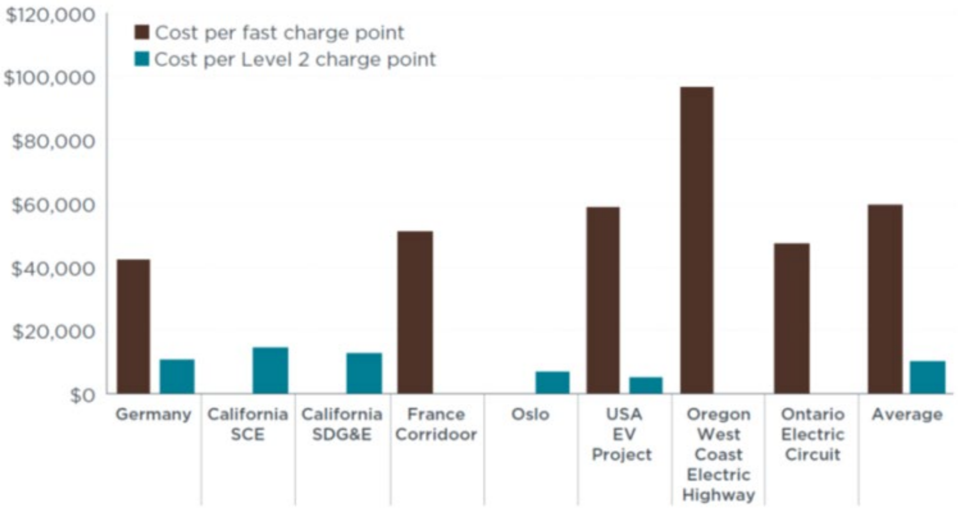

Fig.7: *Approximate program-level costs of L2 and DCFC stations from selected major government charging infrastructure programs.(Source: ICCT, 2017)*

[23] https://afdc.energy.gov/fuels/electricity_charging_home.html
[24] USDOE. "Energy Efficient Mobility Systems Report". Vehicles Technology Office (VTO). FY 2017 Annual Progress Report. p.20.

3.2 Regulations & Policies

Charging equipment installations must comply with local, state, and national codes and regulations. Zoning, codes (including permitting), and parking ordinances are all regulatory tools at the disposal of state and local officials to further the EV readiness of communities. Each has a different potential role to play, and working in tandem can often best encourage the adoption of vehicle charging infrastructure.

Actions are being taken at a state-level and city-level. State-level actions include the low-carbon fuel standards, providing private charger incentives or support for residences and/or commercial businesses, providing public charger promotions such as financial incentives for charging stations at public locations or direct deployment of publicly available infrastructure. At the city scale, numerous actions that promote charging infrastructure include streamlined EVSE permitting processes, EV–ready building codes, EVSE financial incentives or support and city-owned chargers.

Metropolitan area	State action														Local action															Utility action											Total actions (out of 40)
	State ZEV program	State International ZEV Alliance participation	State low carbon fuel policy	State BEV purchase incentive	State PHEV purchase incentive	State increased incentive for low-income	State fee reduction or testing exemption	No state annual electric vehicle fee	State private charger incentive, support	State public charger promotion	State parking benefit	State fleet purchasing incentive	State manufacturing incentive	State allows direct sales to consumers	City electric vehicle strategy	Streamlined EVSE permitting process	EV-ready building code	City vehicle purchase subsidy	City parking benefit	City EVSE incentive, support	City carpool lane (HOV) access	City-owned EV chargers	Workplace charging	City electric carsharing program	City informational materials	City outreach events	City outreach events in low-income communities	City electric vehicle fleet target	City electric buses in public transportation	Utility charging pilot or other research	Utility public charging infrastructure	Utility public charging infrastructure in low-income communities	Utility time of use rates offered	Utility preferential EV rates	Utility EV or EVSE incentive, support	Utility increased incentives for EVSE at multifamily properties	Utility info materials or outreach events	Utility EVSE informational materials for multifamily properties	Utility cost comparison tool	Utility electric vehicle fleet	
Los Angeles	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	34
Sacramento	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X		X		X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	34
San Francisco	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	34
San Jose	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X		X		X	X	X		X	X		X		X	X	X	X	X	X		X		X	X	32
Riverside	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X			X	X	X		X	X				X	X	X	X	X			X	X	X	X	31
San Diego	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X				X	X	X		X	X		X		X	X	X	X	X			X			X	29
New York	X	X		X	X		X	X	X	X		X		X	X	X	X		X		X	X	X	X	X	X		X		X			X	X			X		X		26
Portland	X	X	X	X	X		X		X	X		X		X	X	X						X	X	X	X	X	X	X	X	X	X		X				X		X	X	26
Boston	X	X		X	X		X	X	X	X		X		X			X		X			X	X	X	X	X			X	X			X				X		X	X	23
Denver				X	X		X		X	X		X		X	X		X		X			X	X	X	X	X	X	X	X	X			X				X		X	X	23
Seattle				X	X		X		X	X		X	X	X	X	X		X				X	X	X	X	X		X	X	X							X	X	X	X	23
Baltimore	X	X		X	X		X	X	X	X		X		X								X	X		X	X	X	X	X	X			X	X			X			X	22
Atlanta							X			X			X	X	X	X					X	X	X		X	X		X		X	X		X	X	X		X	X	X	X	21
Philadelphia				X	X			X		X		X		X	X				X			X	X	X	X	X		X	X	X			X		X		X			X	20

"X" indicates that a given electric deployment action was in place in 2017.

ZEV = Zero Emission Vehicle; BEV = Battery electric vehicle; PHEV = Plug-in hybrid electric vehicle; HOV = high-occupancy vehicle lane; EVSE = Electric vehicle service equipment

Fig.8: *EV promotion actions across 14 major U.S. metro areas.(ICCT, 2018)*

An important barrier is the fact that "the federal government has only limited powers in directly influencing or modifying the policies and behavior of the owners or operators of the retail electricity sector. Although the Federal Energy Regulatory Commission (FERC) maintains authority to regulate transmission and wholesale sales of energy in interstate commerce, the retail electricity sector is regulated heavily and almost entirely by individual state regulatory commissions. Thus, the ability of private-investor-owned electric utilities to foster or impede the development of EVs will vary significantly based on the actions of the individual state utility commissions. Furthermore, different regulatory bodies oversee municipal-owned utilities, federally owned utilities, cooperative utilities, and, as indicated, the wholesale markets. These jurisdictional and regional regulatory differences limit the federal government's ability to affect the practices of the U.S. electricity sector."[25]

[25] "Overcoming Barriers to Deployment of Plug-in Electric Vehicles". National Academy of Sciences. p. 98.

3.3 Ownership

The question of who should own charging stations has no simple or universal answer. Since the deployment and operation of charging stations can fall under state authority as a form of public utility, it will be up to each State to decide which approach is best.

“Multifaceted and collaborative approaches have been most successful in promoting early charging infrastructure build-out. Governments at the local, regional, and national levels around the world have used varied strategies to promote public and private charging infrastructure. In leading markets, programs have engaged many stakeholders through integration of driver feedback on charger deployment, implementation of smart charging systems, distribution of funding to local governments, creation of PPPs, and consultation with utilities to minimize grid impacts and limit costs."[26]

According to the Rocky Mountain Institute, “allowing utilities to install and own charging stations could be the fastest way to build them, since utilities have access to large amounts of very low-cost capital and the ability to recover investments over decades. This may also be the easiest path in fully regulated electricity markets, where it would be routine to recover investments in the charging infrastructure through the rate base. It could also serve as insurance against price gouging by private sector companies. […] On the other hand, dedicating the charging station market to the private sector only, and disallowing utility ownership of anything beyond a make-ready point, would likely yield the usual advantages of a competitive market, such as lower cost over time, and more rapid technological and business model innovation. However, the private sector may not be able to deploy charging stations at the speed required by the growth of vehicles, due to the need for large amounts of capital and the lack of a guaranteed demand for charging stations until the EV market matures.”[27]

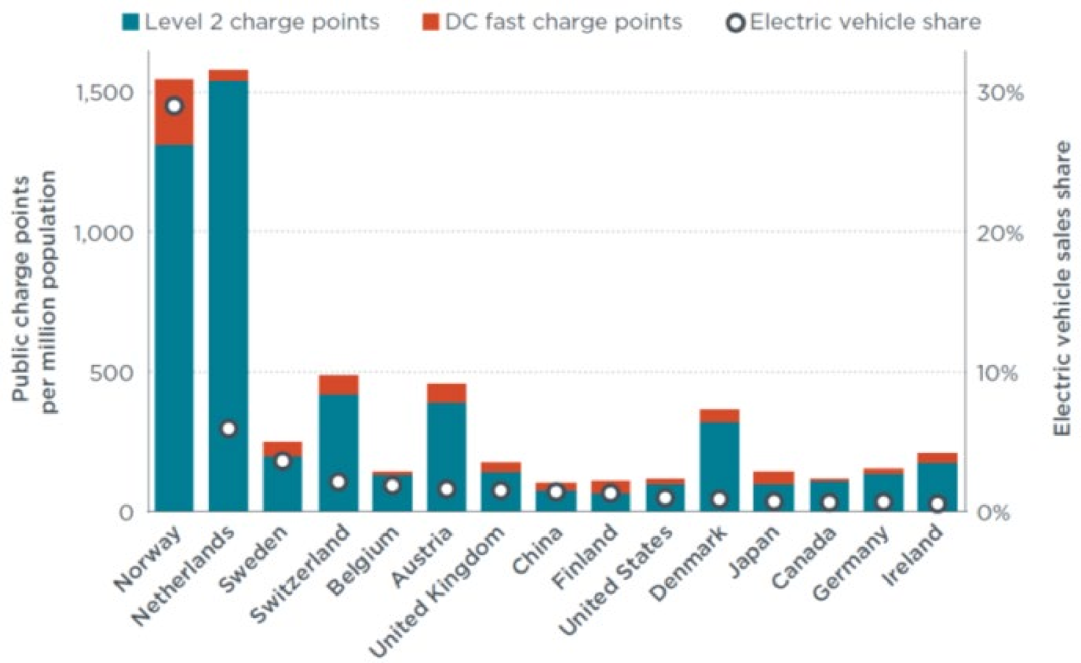

Fig.9: *2016 EV sales shares and public charge points/ million population in major national markets.(ICCT, 2017)*

[26] “Emerging Best Practices For Electric Vehicle Charging Infrastructure”. ICCT, 2017.

[27] "From Gas to Grid: Building Charging Infrastructure to Power Electric Vehicle Demand". Rocky Mountain Institute, 2017.

3.4 Business models

"Actions by governments, utilities, and the industry are leading to a substantial increase in the size of the charging infrastructure network. Government support includes direct deployment, financial incentives for residential or commercial infrastructure, expediting of permitting and installation processes, and adoption of electric vehicle–ready building codes. Similarly, utility actions include direct installation as well as financial incentives for residential and commercial charging stations. Multiple automakers and partner equipment providers are also investing in charging infrastructure to support greater adoption of electric vehicles."[28]

3.4.1 Private charging

A charging station at home is likely to be funded by the homeowner. Financing and logistics of installing home charging infrastructure is not considered to be an important barrier for homeowners who have dedicated parking spots. Other financing models for home charging include the providers' initiative to expand the subscription-based charging into providing residential charging infrastructure as part of their subscription service. Utilities might also have an interest in providing residential charging infrastructure as it would increase electricity usage at the residence.

Multi-unit dwellings (MUDs) charging faces more barriers, and it is not clear if owners of complexes, drivers of vehicles, or municipalities have incentive to install EVSE. Apartment owners possible benefits include earning points toward LEED certification, their property being marketed as green and increasing rents by offer charging as an attractive amenity to prospective renters. A neighborhood-based approach to EV charging for residents of MUDs is being developed by the City of SF, in cooperation with the Center for Sustainable Energy and funding from the CA Energy Commission. The approach plans for the deployment of EVSE to the 2/3 of the population who lives in MUDs. Based on a study of driver locations, infrastructure needs and charging availability, the equipment will be installed in MUD garages and close parking lots.

Workplaces charging is likely to be funded by the businesses or organizations. Utility also has interest in installing workplace charging stations earning additional revenue from the sale of electricity at worksites. Demand charges could increase the cost of electricity to the employer and that could be a cost barrier to workplaces installing charging for employees. Some employers may as well choose to contract with charging providers to install and operate charging infrastructure, including charging for the electricity provided.

According to an ICCT report of 2017 called "Emerging Best Practices For Electric Vehicle Charging Infrastructure" (p. 30-33), private home charging represents the majority of electric vehicle charging using L1 or L2 charging equipment. As technologies evolve, higher-capacity home L2 charging stations become essential but costly. Except the cost of the charger itself, the upgrades of the existing electrical wiring to accommodate the high power consumption and the safety equipment increase the upfront costs. For this reason both Government operate programs and incentives offered by utility companies could try to cover such added costs in order to make EVs accessible to all and increase the viability of their driving range in the future. Also, Governments are starting crafting regulations that mandate "make-ready EV infrastructure" in buildings[29] and parking spaces.

[28] "Expanding The Electric Vehicle Market In U.S. Cities". ICCT, 2017. p.6.

[29] One pioneering use of building requirements to promote EVs was CA's Green Building Standards Code, which required in 2015 that 3% of all parking spaces in commercial buildings include make-ready infrastructure for charging stations. (ICCT, 2017)

3.4.2 Public charging

Things become more complicated and costly to build and operate as the charging becomes more publicly accessible and delivers faster charging. Potential owners and operators of public charging infrastructure are the retailers, the electric utilities, commercial charging providers (ChargePoint) and Federal Government.

The ICCT report "Emerging Best Practices for Electric Vehicle Charging Infrastructure" (p. 28-29) analyzes possible business models for public charging. According to the report, public infrastructure business case still remains a challenge due to its large upfront costs and the lack of investors. Indirect revenues and policies can improve that by increasing private investments. The report emphasizes the role of Federal funding in addition to commercially sustainable charging infrastructure through business models which are based on electricity sales, increased retail sales, advertising revenue and automaker funded stations.[30]

"Federal Governments can be effective at influencing EV deployment although in order to ensure that charging infrastructure developers have an incentive to site chargers so that they will be well used, government infrastructure funding should comprise only a portion of the funding for a charging station and should not go toward stations that would be deployed without government funding."[31] From their part, States could do the following to increase funding for charging infrastructure: [32]

- Work with state legislatures to provide financial incentives for charging infrastructure.
- Work with utilities to provide financial incentives for and to invest in charging infrastructure.
- Join or start a carbon pricing program that generates revenue that could be used for charging infrastructure.
- Direct state departments of transportation to consider ways to incorporate charging infrastructure into their investment plans.
- Apply for federal grants.

Utility companies could emerge as a willing source of capital for public charging stations. "Theoretically all utilities servicing a given geographical area would collectively have a viable business model if there were a mechanism to (1) separate out and pool the electricity sales to all households that owned PEVs within that area and (2) share the revenues from that pool in proportion to the amounts that the different utilities contributed to investments in public charging infrastructure. Such a mechanism would not have to rely on government subsidies or cross subsidization from households that did not own a PEV. That said, whether utilities that invested their own capital in charging stations could earn a respectable rate of return over time would depend on state level regulatory policies that are used to encourage utility investment."[33]

Private sector is also mobilized and in response to government grants has entered the EV market by installing and managing public charging stations. These are located both between cities and within. The companies have been experimenting with different models in their efforts to recover their capital costs and the costs of electricity. For example, ChargePoint

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[30] The most obvious example of this is Tesla's proprietary Supercharger network, consisting of 5,043 charge points at 790 locations, 2,636 of those in North America (as of December 31, 2016) (ICCT, 2017).

[31] "Overcoming Barriers to Deployment of Plug-in Electric Vehicles". National Academy of Sciences. p. 94

[32] https://www.americanprogress.org/issues/green/reports/2018/07/30/454084/investing-charging-infrastructure-plug-electric-vehicles/

[33] "Overcoming Barriers to Deployment of Plug-in Electric Vehicles". National Academy of Sciences. p. 93.

(2014) is pricing on a per-charge-event basis while NRG/eVgo (2014) relies on both a monthly subscription fee and a fee per minute of plug-in time.

Vehicle manufacturers are the private sector's most motivated investor to install fast charging along intercity and interstate highways, as this type of infrastructure is the most expensive to build and is unlikely to generate high returns from for-pay charging. Unfortunately, in the absence of government subsidies, it seems unlikely that any companies other than BEV manufacturers could have a business case for covering the installation and maintenance costs of DCFC. Also a vehicle manufacturer would have little incentive for providing charging infrastructure for PEVs that it did not produce.[34]

Country	Program	Budget	Mechanisms of support
China	• State Grid national fast charging corridors • Regional investments by automakers • City government-funded construction in pilot cities		• State-owned utility programs • Public-private partnership • Grants to local governments
France	• Funding given 3,000 cities for 12,000 charge points • EDF power company building nationwide DC fast charging network		• Local governments apply for grants
Germany	• €300 million for 10,000 Level 2 and 5,000 DC fast charging stations	€300 million ($285 million)	• Subsidies for 60% of costs for all eligible businesses
Japan	• Next Generation Vehicle Charging Infrastructure Deployment Promotion Project • Nippon Charge Service government-automaker partnership	Up to ¥100 billion ($1 billion)	• Grants to local governments and highway operators • Public-private partnership
Netherlands	• "Green Deal" (curbside chargers on request)	€33 million ($31 million)	• Contracts tendered to businesses on project-by-project basis
Norway	• Enova grant scheme from 2009 onward		• Quarterly calls for proposals for targeted projects
United Kingdom	• Curbside stations for residential areas • Highways England building DC fast charging stations along major roads in England	£2.5 million ($2 million) £15 million ($12 million)	• Municipalities apply for grants; installers reimbursed • Grants and tenders administered by public body
United States	• Grants for funding public charging stations through American Recovery and Reinvestment Act	$15 million	• Matching grants for local governments

Fig.10: *Summary of major national-level charging infrastructure programs in selected markets, including budget and form of award. (Source: ICCT,2017)*

[34] For example, Tesla has launched a program to install several hundred supercharging stations along major long-distance transportation corridors throughout the United States but only Tesla customers can use them because of a Tesla-specific plug.

CONCLUSIONS

Many factors contribute to spurring the growth of the market for electric vehicles and it is critical to get right the methods and infrastructure for vehicle electrification from the start, well-planned infrastructure, appropriate tariffs, and the ability to manage.

First and foremost, EV market growth requires many actions by many different players. Local, state, and utility stakeholders are reducing consumer barriers with policy, fiscal and non-fiscal incentives, infrastructure built out, awareness campaigns or electrification of public transit and government vehicle fleets. Not one nor two stand alone actions are sufficient to promote EV adoption. Having an extensive public charging infrastructure per capita is not enough unless it is supported by incentives, model availability and promotion actions. On the other hand, having substantial consumer purchase incentives and lack charging infrastructure deployment actions or utility actions also leaves you in an average vehicle uptake.

The cost of the EVs themselves remains important. The target should be lower cost and increased range. Their infrastructure increases community awareness and drivers confidence, whereas more EV users increase demand for infrastructure. This shows the interdependency of EV adoption and the various types of charging infrastructure.

Electricity demand and supply needs careful management. With careful planning and early intervention, the EV revolution can help optimize the grid instead of overloading it and can reduce the unit cost of electricity, while increasing the share of renewable electricity and reducing emissions in the energy and transportation systems. Negative impacts of an inefficient electricity generation capacity could be higher costs, an instable and unsupportive charging network and regulatory conflicts.

EV capitals are emerging as global leaders in terms of EV promotion actions and uptake, and are already realizing the benefits of their investment in clean transportation. Although EV policies and actions must be tailored locally, each metropolitan area can provide a model for others. This type of leadership, if continued and expanded, will help accelerate the global deployment of electric vehicles in coming years.

ACRONYMS

AC	Alternating Current
DCFC	Direct Current Fast Charge
EPA	Environmental Protection Agency
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GHG	Greenhouse Gas
ICCT	International Council on Clean Transportation
L1	Level 1 charging station
L2	Level 2 charging station
LBNL	Lawrence Berkeley National Laboratory
NEPA	National Environmental Policy Act
NREL	National Renewable Energy Laboratory
PEV	Plug-in Electric Vehicle (EV & PHEV)
PHEV	Plug-in Hybrid Electric Vehicle
SEPA	Smart Electric Power Alliance
TOU	Time-Of-Use
USDOE	U.S. Department of Energy
V2G	Vehicle-to-Grid
VGI	Vehicle-Grid Integration
ZEV	Zero Emission Vehicle

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