ENERGY
MARKETERS
OF AMERICA
EMA

December 2020

Utility Investments and Consumer Costs of Electric Vehicle Charging Infrastructure

DISCLAIMER

This report was commissioned by the Energy Marketers of America. The findings and views expressed in this study are those of the authors and may not represent those of the sponsoring organizations.

Author:
Venki Venkateshwara

Venki Venkateshwara is a Managing Director at FTI Consulting, Inc. who specializes in the regulatory structure and economics of all parts of the electric industry – generation, transmission, and distribution. He has led studies on energy infrastructure, renewable energy technology, greenhouse gas policies, electrification policies, and modeling of electric markets in the U.S. including CAISO, ISO New England, MISO, NYISO, PJM, and SPP. Mr. Venkateshwara holds a Ph.D. in Energy Management and Policy from the University of Pennsylvania, as well as an MBA from the Wharton School. He earned a B.S. in Mechanical Engineering from the Indian Institute of Technology.

Table of Contents

Executive Summary

Electric vehicle ("EV") advocates in in different states have been pushing for electric utilities to invest in EV charging infrastructure with recovery of these investments through electric rates. Under such an approach, all electric utility customers, including those that do not own EVs, would be obligated to reimburse the electric utility company for this additional infrastructure through their electric rates – a question glossed over in public policy debates.

Key Takeaways

The key study takeaways are as follows:

- EV infrastructure costs about $5,100 per EV, over an average 10-year on-the-road lifetime
- Total investments could amount to $35–$146 billion by 2030, depending on EVs on the road
- If these costs were borne solely by EV owners, each owner would have to pay more than $500 a year per EV or $9 every time they completely charge their 75-kWh battery vehicle.
- Many utilities and EV advocates want to socialize these costs, meaning all electric utility customers pay more while only EV owners reap the benefits.

Study Focus, Approach, and Scenarios

This study focuses on three questions surrounding EV-related distribution and transmission buildout:

- What is the cost of building the distribution and transmission infrastructure required to support EV fleet expansion or meet policy-prescribed expansion targets?
- Depending on how infrastructure expansion will be funded, what are the implications for EV owners, non-EV owners, and electric utility customers?
- What are the economic impacts of EV infrastructure expansion?

This study examines the infrastructure required under the three scenarios shown in Table ES-1.

Table ES-1: Scenario Descriptions

Scenario Name	U.S. EV Stock by 2030		EV Market Penetration Basis
	Light Duty EVs	On-Road Freight EVs	
EV – AEO	8.4 million	10 thousand	Annual Energy Outlook ("AEO") 2020 – Reference Case
EV – 18 MM	18.0 million	460 thousand	Based on 100% light-duty EV sales and 100% on-road freight truck EVs sales by 2050[a/]
EV – 30 MM	30.0 million	690 thousand	Based on 100% light-duty EV sales by 2035 and 100% on-road freight truck EV sales by 2040 [a/]

[a/] EV-30 MM: House Majority Staff Report, *Solving the Climate Crisis,* June 2020; EV-18 million stretches out EV 100% date to 2050 relative to Staff Report

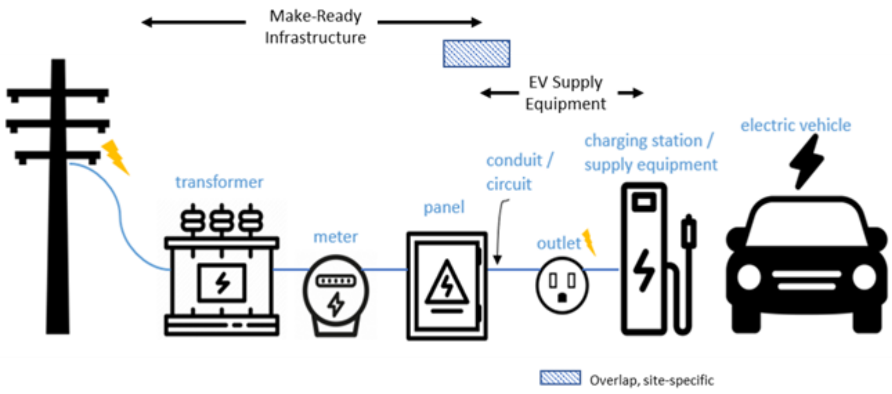
Cost of EV Infrastructure Expansion

Key Infrastructure Components

There are two types of key infrastructure enhancements – electric distribution and transmission – required to provide adequate and readily accessible electric power to charge EVs under high EV penetration scenarios. Distribution refers to the low voltage system of wires and electric facilities to deliver power from the high voltage transmission system to the end-user. Transmission is the high voltage system that accepts power from electric generation plants and delivers the power to high voltage substations close to load centers for eventual distribution to end-users.

Within distribution, there are charging station investments or "EV Supply Equipment" at homes and public locations (i.e., along highway corridors, offices, and commercial establishments), and there are supporting distribution grid enhancements or "Make-Ready Infrastructure." Figure ES-1 illustrates and explains these two types of distribution investments.

Figure ES-1: EV Distribution Infrastructure Components



- EV Supply Equipment (EVSE): EVSE is the equipment and wiring that connects the electric system at a site to the EV. This includes the charger itself (L1, L2 or L3), as well as the trenching and conduits at the site and the electrical panel.
- Make-Ready Infrastructure: This component refers to the electrical infrastructure from the grid to the panel at the site of the EVSE and includes distribution lines, transformers, and meters. Much of this infrastructure is on the utility side of the meter and is necessary to build out the electrical grid.

In addition to Make-Ready infrastructure enhancements at the distribution level, electric utilities will need to invest in transmission enhancements to support the electric grid given increased power demands and changes in power flow patterns. These transmission investments include, for example, increases in high voltage transformers at some locations, as well as system reinforcements to handle higher distribution system loads. EV transmission-related investments are projected to cost approximately one-third of distribution-related investments.

Residential and Public Charging

Three levels of chargers are generally available. A Level 1 ("L1") charger uses a 120-volt AC supply, while a Level 2 ("L2") charger uses a 208/240-volt AC supply. The fastest charger type available currently is a direct-current fast charger ("DCFC") or Level 3 charger. A DCFC uses a 3-phase 480-volt AC supply to deliver direct current to the vehicle. Table ES-2 summarizes the various EVSE charger types for residential and public areas, representing different kW ratings, charging rates, and costs.

Table ES-2: Characteristics of Residential and Public Chargers by Type

Charger Type	Voltage	Typical Power	Miles per Charging Hour	Estimated Time to Re-charge[1/]	Average Cost per Charger
Residential – L1	120 V AC	1.2-1.6 kW AC	1-5 miles	50 hours	< $1,000
Residential – L2	208-240 V AC	3.3-6.6 kW AC	10-20 miles	15 hours	$2,600
Public – L2	208 V-240 V AC	7.2-19.2 kW AC	20-70 miles	3.75 hours	$12,500
Public – DCFC	480 V DC	50-350 kW DC	200-600 miles	0.5 hours	$136,000

[1/] Based on 75 kWh battery

Source: NREL, RMI, other industry studies; FTI analysis

Table ES-2 provides two main takeaways. First, a Level 2 charger may not fully charge a 300-mile EV overnight. Second, even the fastest chargers will need 30 minutes or more to fully charge an EV.[1]

EV Infrastructure Investments and Cost-Recovery

By 2030, EV infrastructure investment costs, including the investment costs for distribution enhancements and associated transmission investments could range as high as $146 billion under the EV-30MM scenario, as shown in Table ES-3.

Table ES-3: Cumulative Investment Cost of EV Infrastructure Buildout, 2019-2030

EV Investment Cost Category	EV – AEO	EV – 18 MM	EV – 30 MM
Distribution investments	$26.6 billion	$64.3 billion	$109.9 billion
Associated transmission investment	$8.8 billion	$21.2 billion	$36.3 billion
Total	**$35.4 billion**	**$85.5 billion**	**$146.2 billion**

These assumptions translate to a cost of $3,800/EV and $1,300/EV for distribution and transmission costs respectively, for a total of $5,100/EV. If only EV owners were to bear these costs, they would

---

[1] Notably, a comparable refueling time for an internal combustion engine car under 2 minutes. Also, as a matter of good practice, EV owners are encouraged not to use fast charging consistently or to completely recharge their EV to 100% as both practices can lead to battery degradation. See https://news.ucr.edu/articles/2020/03/11/fast-charging-damages-electric-car-batteries and https://insideevs.com/news/368097/video-60-percent-ev-charge-limit-benefitshttps://insideevs.com/news/368097/video-60-percent-ev-charge-limit-benefits.

have to pay an additional $9 every time they recharge, assuming a 75 kWh battery.[2] In annual terms, each EV owner would have to pay $500 a year to cover the costs of infrastructure. EV advocates argue, however, that these costs should be socialized among all electric utility customers to accelerate EV infrastructure buildout, meaning that EV owners would benefit, at the expense of all other electric utility customers. The cost socialization approach also ignores the incentive it gives electric utilities, which are allowed to recover their costs through rates, to over build infrastructure.

Even with non-EV customers likely subsidizing future EV infrastructure investment by utilities, some EV advocates have asked for more subsidies. They assert that under standard tariffs, EV owners pay too much for electricity at public charging stations because of demand charge.[3] As a result, EV advocates have pushed to create exceptions to limit demand charges or fix rates for public charging without regard to the costs they place on the electric system.

Economic Impacts

It is important to consider the benefits of increased investments and the additional costs borne by electric utility customers when examining the economic impacts of EV infrastructure buildout. Distribution and transmission investments made in the utility sector will generate increased economic activity for utilities and their supply chains, such as construction and manufacturing. However, higher costs borne by electric utility customers to repay these investments will decrease real income of households and businesses.

Table ES-4 illustrates the range of labor income and job losses across the three scenarios examined.

Table ES-4: Annual Average Labor Income and Jobs Losses across Scenarios

Impact Category[4]	EV – AEO	EV – 18 MM	EV – 30 MM
Labor Income Lost, Average of 2019–2030	$1.0 billion	$2.4 billion	$4.1 billion
Jobs Lost, Average of 2019–2030	27,900	67,500	115,300

Table ES-4 shows that labor income and jobs would be lost even with increased investment. This is because real income losses for households from higher electricity and general consumer prices would have a higher impact on these metrics than spending and economic activity from EV infrastructure buildout.

---

[2] Derived from $5,100/EV incurred over 10 years, 12,718 VMT/EV/year, 3 miles/kWh, and 75 kWh battery.

[3] Demand charges are a common component of rates for large power users that charge them for the kW of demand (distinct from kWh) they place on the system. When utilization rates (e.g., at a public charging station) are low these charges act like a fixed cost and drive up the effective rate paid per kWh.

[4] Impact focused solely on EV infrastructure impacts and does not include broader macroeconomic impacts such as losses in petroleum, biofuels, and auto manufacturing.

Cost of Utility Infrastructure to Support EVs

EV advocates sometimes frame the lack of readily accessible charging for EVs as a "chicken and egg" issue. That is, they say, without adequate access to charging, customers will be hesitant to buy EVs. At the same time, justifying significant infrastructure investment depends on forecasts for EV fleet growth.

To address this issue, EV advocates have promoted EV market penetration targets and encouraged electric utilities to proactively invest in EV charging infrastructure so customers can readily access chargers at home or in public locations, which include points along highway corridors, offices, and commercial establishments such as hotels and malls, or at apartment complexes.

For this study, EV infrastructure cost estimates were developed using the following approach:

- Review and compile utility information (e.g., filings to support planned investments in charging infrastructure and information on costs of completed installations) from seven states – California, Florida, Minnesota, New Jersey, New York, Pennsylvania, and Washington;[5]
- Review and compile information from public studies released by institutions such as the National Renewable Energy Laboratory ("NREL") and Rocky Mountain Institute ("RMI");
- Organize cost information separately for residential and public charging infrastructure;
- Categorize information into the two major distribution infrastructure components – EVSE and make-ready infrastructure;
- Standardize information and restate in terms of $ per EV;
- Estimate associated transmission costs; and
- Apply three distinct scenarios to book-end projections of EVs (see Table 1) below to develop estimates of nationwide and state-level EV charging infrastructure costs.

---

[5] The study initially focused on Florida, Minnesota, New Jersey, and Pennsylvania as emerging high potential EV states with sizable urban populations. Data from other states was included to better estimate a range of infrastructure costs.

Table 1: Scenario Descriptions

Scenario Name	U.S. EV Stock by 2030		EV Market Penetration Basis
	Light Duty EVs	On-Road Freight EVs	
EV – AEO	8.4 million	10 thousand	Annual Energy Outlook ("AEO") 2020 – Reference Case
EV – 18 MM	18.0 million	460 thousand	Based on 100% light-duty EV sales and 100% on-road freight truck EVs sales by 2050[a/]
EV – 30 MM	30.0 million	690 thousand	Based on 100% light-duty EV sales by 2035 and 100% on-road freight truck EV sales by 2040 [a/]

[a/] EV-30 MM: House Majority Staff Report, *Solving the Climate Crisis,* June 2020; EV-18 million stretches out EV 100% date to 2050 relative to Staff Report

The EV-30 MM scenario, based on a recent House Majority Staff Report that sets a goal of 100% light duty EV sales by 2035 is one end of the scenarios considered here.6 The Department of Energy's 2020 Annual Energy Outlook assumes no future policy changes and represent the other end of the scenarios.

Types of Charging Infrastructure

EV infrastructure includes the charger as well as the investments in lines, transformers, and meters to enable the charger to take power from the grid. The charger is one piece of the electric vehicle supply equipment (EVSE), as further discussed below. As a stand-alone piece of equipment, chargers vary in terms of their voltage, kW rating, and time required to deliver charge. Industry definitions distinguish between three types of chargers:

- **Level 1 ("L1") Chargers:** L1 chargers use a 120-volt (V) alternating current and can be plugged into standard home wall sockets. The vast majority of EV owners are likely to find L1 charging rates to be inadequate – e.g., a 75-kWh battery will require 50 hours to charge completely.
- **Level 2 ("L2") Chargers:** L2 chargers for residential use provide 10 to 20 miles of range for every hour of charging and use 208 V or 240 V electrical service, requiring additional infrastructure costs at the charging location. Residential L2 chargers require 15 hours to completely charge a 75-kWh battery. Public versions of Level 2 chargers have higher kW draws and require infrastructure at the charger location to be connected to the grid. These public chargers can charge a 75-kWh completely in 3.75 hours.

---

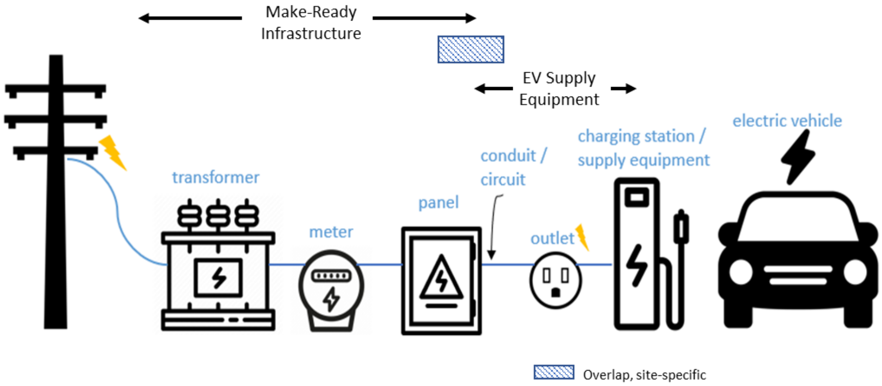
[6] https://climatecrisis.house.gov/report

- **Direct-Current Fast Charging ("DCFC"):** DCFC fast charging can provide 200 to 600 miles of range per charging hour. These chargers operate at voltages as high as 480kV and draw power of 50 kW to 350 kW. A DCFC can charge a 75-kWh battery completely in 30 minutes. DCFCs are suitable only for public charging stations.

EV Infrastructure Components

There are two types of key infrastructure enhancements required to provide adequate and readily accessible fuel to power EVs under high EV penetration scenarios – distribution and transmission investments. Within distribution, there are charging station investments or "EV Supply Equipment" at homes and public locations (i.e., along highway corridors, offices, and commercial establishments), and there are supporting distribution grid enhancements or "Make-Ready Infrastructure." Figure 1 illustrates and explains these two types of distribution investments.

Figure 1: EV Distribution Infrastructure Components



- **EV Supply Equipment (EVSE):** EVSE is the equipment and the wiring that connects the electricity system at a site to the EV. This includes the charger itself (L1, L2 or L3), as well as the trenching and conduits at the site and the electrical panel.
- **Make-Ready Infrastructure:** This component refers to the electrical infrastructure from the grid to the panel at the site of the EVSE and includes distribution lines, transformers, and maters Much of this infrastructure is on the utility side of the meter and is necessary to build out the electrical grid.

Depending on the cost study, the line between EVSE and Make-Ready Infrastructure is not always clear, making some overlap among site-specific assessments inevitable.

In addition to Make-Ready distribution infrastructure enhancements, electric utilities will need to invest in associated transmission enhancements to support the electric grid given increased power demands and changes in power flow patterns. These transmission investments include, for example, increases in high voltage transformers at some locations, as well as system reinforcements to handle higher distribution system loads. EV transmission-related investments are projected to total approximately one-third of distribution-related investments.

Residential Charging

Like conventional automobiles, light-duty EVs mainly will be used to commute from home to work, run errands, and make occasional road-trips. This means that charging EVs at home will be the most convenient. In fact, the available research suggests that charging will occur primarily at home.[7] For apartment dwellers owning EVs, they likely will rely more on public chargers at offices, malls, or other public locations as the availability of chargers at apartment complexes will often be limited by space.

With typical commuting between the home and office, each EV in a household will require between 40 and 60 miles of charge every day.[8] At that daily charge level, L1 chargers will be inadequate for most households as they would take 13 hours for about 40 miles of charge or as much as 50 hours to completely fuel a 75-kWh battery (300-mile equivalent).[9] L2 chargers, however, can provide 15 miles of range for every charging hour, on average, and represent a practical alternative. An L2 charger can provide about 45 miles of charge with 3 hours of charging and can completely fill a 75-kWh battery in 15 hours as shown in Table 2. The estimated time to charge is based on average conditions. In practice, the onboard battery management system may limit charging rates when ambient temperatures are low to avoid damage to the battery.[10]

Table 2: Characteristics of Residential Chargers by Type

Charger Type	**Voltage**	**Typical Power**	**Miles per Charging Hour**	**Estimated Time to Re-charge**[11]
Residential – L1	120 V AC	1.2-1.6 kW AC	1-5 miles	50 hrs.
Residential – L2	208-240 V AC	3.3-6.6 kW AC	10-20 miles	15 hrs.

Source: NREL, RMI, other industry studies; FTI analysis

EV charging places significant additional load on the utility distribution system. Relative to a monthly peak of 2.5 kW to 3.5 kW for a typical single-family home, a single L2 charger adds about 5 kW to 6 kW of load during charging.

The additional load incurred by EVs can exacerbate utility peaks as the most convenient time for EV owners to start charging their vehicles is often between 5 pm and 7 pm when they return from work. This is also the time when utility system loads are relatively high, if not at their peak, as lighting,

---

[7] Idaho National Laboratory, *Plugged In: How Americans Charge Their Electric Vehicles*, *Plugged In: How Americans Charge Their Electric Vehicles*, September 2015.

[8] Assumed a battery electric vehicle for calculation purposes.

[9] The size of battery varies by EV model. Some EVs such as the Ford Bolt have a battery of 60 kWh, while others like Tesla Model X have a battery of 100 kWh. As noted, the popular Tesla Model 3 has a 75-kWh battery. The range is a function of battery size and efficiency, which is related to vehicle weight.

[10] https://phys.org/news/2018-08-ev-cold-temperatures-pose-drivers.html

[11] Based on 75 kWh battery

heating, venting and cooling equipment, household appliances, and other electric devices get turned on or used more intensively.

Electric utilities will have to plan for an increased peak on the distribution system, increasing make-ready infrastructure costs. Actions that will be required and will increase make-ready costs include reconductoring of existing lines, adding entire stretches of new line, enhancing transformer capacity or installing new transformers with higher ratings (to replace old, ageing transformers), and installing new meters, as needed.

Public Charging

As EV penetration increases as contemplated in the two policy scenarios presented in this report, public charging access will need to grow accordingly. A study by the Idaho National Laboratory found that over 80% of the battery charging done by EV owners occurred at home.[12] However, the same study showed that only a small subset of this group (5% to 13%) charged their EVs solely at home. The availability of public charging, therefore, is important not only for those without access to home charging, such as those who live in apartments, but also for residential EV owners for whom public charging provides a convenience, such as charging while at work. Additionally, public charging is essential to mitigate EV owner concerns that they could run out of fuel (battery charge) when on road trips.

The degree of utility infrastructure in close proximity to planned charging stations will be situation specific. This means that major distribution lines of substantial length along with new distribution transformers will have to be added to accommodate site-specific charging station needs. Even if utility infrastructure exists close to the charging station, the power required for a public charging station will be large enough to require major infrastructure expenditures.

Public charging will require either public L2 chargers or DCFCs as shown in

Table 3. While L2 public chargers and DCFC chargers provide about ten times more miles of charge per hour than residential chargers, even the fastest chargers will need 30 minutes or more to fully charge an EV. This is in comparison to internal combustion engine vehicles for which the comparable time to refuel (at 10 gallons per minute) is under two minutes. As a matter of good practice, EV owners are encouraged not to use fast charging often or completely refuel to 100%. Both practices can lead to battery degradation.

---

[12] McFarlane, Dane, Matt Prorok, Brendan Jordan, and Tam Kemabonta, “Analytical White Paper: Overcoming Barriers to Expanding Fast Charging Infrastructure in the Midcontinent Region,” Great Plains Institute (July 2019), citing Idaho National Laboratory, “Plugged In: How Americans Charge Their Electric Vehicles” (2015).

Table 3: Characteristics of Public Chargers by Type

Charger Type	Voltage	Typical Power	Range per Charging Hour	Estimated Time to Re-charge[1/]
Public – L2	208 V-240 V AC	7.2-19.2 kW AC	20-70 miles	3.75 hours
Public – DCFC	480 V DC	50-350 kW DC	200-600 miles	0.5 hours

Source: NREL, RMI, other industry studies; FTI analysis

Charging Infrastructure Cost Estimates

Cost estimates for engineering systems or sub-systems always have site-specific components that add uncertainty to costs and schedules. The estimating challenge is partly mitigated when good data exists based on historical experience at different sites and under different circumstances. In such situations, the relationship between key variables and cost can be characterized in detail and the site-specificity can be accounted for by applying site-specific parameters.

Available data show that cost estimates for EVSE and Make-Ready distribution infrastructure have wide ranges. The available data include:

- Very limited experience with actual installations, confined mainly to electric utility pilot EV charging programs.
- Applications by electric utilities to public utility commissions for approval of additional pilots, which often provide only engineering-based estimates of siting requirements, costs and projections.
- Published estimates (often generic and characterized by a range) from research organizations, such as NREL and RMI.

Cost estimates compiled from various utility filings and other public filings on a per charger basis are presented for residential and public charging in the following subsections.

Residential Infrastructure Cost Estimates

Table 4 below summarizes estimated costs for residential L2 chargers.

Table 4: Cost of Residential L2 Chargers

State/Source	Utility	Networked[13]	EVSE	Make-Ready Infrastructure	Total Cost, $ per EV	Source/Notes
WA	Avista	No	$515	$1,253	$1,768	Avista Corp., 2019
WA	Avista	Yes	$1,061	$1,384	$2,445	Avista Corp., 2019
NJ	PSE&G	Yes	$1,091	$1,423	$2,514	PSEG, 2018
CERES/Bradley Report	N/A	Yes	$1,515	$1,337	$2,853	MJ Bradley & Associates, LLC, 2017
Derived: generic EVSE + make-ready mid-point estimate from California DER study	N/A	Yes	$1,061	$1,289	$2,350	RMI; DNV-GL
Derived: generic EVSE + make-ready estimate on congested feeder from California DER study	N/A	Yes	$1,061	$2,431	$3,492	RMI; DNV-GL
				Average (rounded)	$2,600	

Because L1 chargers can be plugged into the wall sockets, their cost mainly will be in Make-Ready Infrastructure and can be expected to be less than $1,000 per charger. It is reasonable to expect that L2 chargers will dominate the residential charging market, however, given the inadequate time to charge with L1 equipment. Residential L2 costs vary widely from $1,800 to $3,500 per charger.

Public Infrastructure Cost Estimates

Table 5 below summarizes estimated costs for public versions of L2s. Costs for DCFC are an order of magnitude higher than L2s. DCFC cost ranges were examined separately in Table 6. The DCFC chargers in Table 6 vary in power rating from 50 kW to 150 kW, although these chargers can have a power rating as high as 350 kW.

---

[13] Networked refers to chargers that are connected to the internet and provide real-time visibility to the utility; non-networked chargers do not provide such visibility.

Table 5: Cost of Public L2 Chargers

State/Report	Utility	EVSE	Make-ready infrastructure	Total Cost, $/charger	Source/Notes
NJ	ACE	$6,741	$8,259	$15,000	Atlantic City Electric Company, 2018
MN	Ottertail	$5,000	$6,125	$11,125	Otter Tail Power Company, 2020
MN	Xcel	$5,505	$6,745	$12,250	Xcel Energy, 2018
WA	Avista	$4,610	$5,648	$10,258	Avista Corp., 2019
PA	DLC	$5,500	$6,340	$11,840	Duquesne Light Company, 2020
CA	SCE	$6,636	$8,129	$14,765	Southern California Edison Company, 2020
NY-Metro	N/A	$5,818	$8,187	$14,005	Atlas Public Policy, 2019, Department of Public Service New York, 2020
NY-Upstate	N/A	$6,547	$4,500	$11,047	Atlas Public Policy, 2019, Department of Public Service New York, 2020
CERES/Bradley Report	N/A	$5,412	$6,742	$12,154	MJ Bradley & Associates, LLC, 2017
			Average (rounded)	$12,500	

Note: The split between EVSE and make-ready imputed in some cases

Table 6: Cost of Public DCFC Chargers

State/Report	Utility	EVSE	Make-ready Infrastructure	Total Cost, $/charger	Source/Notes
NJ	PSE&G	$43,448	$94,330	$137,778	PSEG, 2018
NJ	ACE	$37,842	$82,158	$120,000	Atlantic City Electric Company, 2018
MN	Ottertail	$45,869	$99,586	$145,455	Otter Tail Power Company, 2020
MN	Xcel	$44,228	$96,022	$140,250	Xcel Energy, 2018
WA	Avista	$40,391	$87,693	$128,084	Avista Corp., 2019
NY-Metro	N/A	$30,000	$119,373	$149,373	Department of Public Service New York, 2020
NY-Upstate	N/A	$30,000	$82,985	$112,985	Department of Public Service New York, 2020
CERES/Bradley report	N/A	$59,534	$94,592	$154,126	MJ Bradley & Associates, LLC, 2017
			Average (rounded)	$136,000	

Estimated U.S. Infrastructure Costs by Scenario

Infrastructure costs for the three charger types – residential, public L2, and public DCFC – are summarized in Table 7 based on the range of estimates shown in Table 4, Table 5 and Table 6.

Table 7: Range of Public Per Charger Cost

Charger type	Low end, $/charger	High end, $/charger	Average, $/charger
Residential L2 charger	1,800	3,500	2,600
Public L2 chargers	10,000	15,000	12,500
Public DCFC charger	110,000	155,000	136,000

Table 8 below shows the incremental additions by scenario of EV LDVs and EV on-road freight vehicles from 2019 and 2030, as well as the incremental public L2 chargers and public DCFC chargers required based on the estimated numbers of such public chargers required for every 1000 EVs.[14]

Table 8: Incremental EVs and Public Chargers Required

Data item	Calculation	EV – AEO	EV – 18 MM	EV – 30 MM
2019 EV Light Duty, millions	[a]	1.51	1.51	1.51
2030 EV Light Duty Stock, millions	[b]	8.4	18.0	29.7
2030 Incremental EV Light Duty Stock, millions	[c] = [b] – [a]	6.9	16.5	28.2
2019 EV On-road Freight	[d]	0	0	0
2030 EV On-road Freight, millions	[e]	0.01	0.46	0.69
2030 Incremental EV On-road Freight, millions	[f] = [e] - [d]	0.01	0.46	0.69
2030 Total Incremental EV's (LD + On-road Freight), millions	[g] = [c] + [f]	6.9	17.0	28.9
2030 Public L2 chargers[15]	60 x ([g]/1000)	413,195	1,017,024	1,734,413
2030 Public DCFC chargers[16]	4 x ([g]/1000)	27,546	67,802	115,628

Source: EIA, House Select Committee Staff Report, FTI analysis

---

[14] Based on the different data sources used here, it is reasonable to assume that the $/charger cost reflects one vehicle per charger at a given time. Therefore, for residential charging, chargers required equals number of EVs.

[15] Assumption of 60 public L2 chargers required per 1,000 EVs

[16] Assumption of 4 public DCFC chargers required per 1,000 EVs

The incremental distribution infrastructure cost is then derived for residential, public L2, and public DCFC as follows:

- Residential charging infrastructure cost = (Scenario specific incremental EV LDVs) * ($ per charger)[17]
- Public L2 charging infrastructure cost = (Scenario specific incremental EV LDVs + EV on-road freight) * (0.06) * ($ per charger)[18,19]
- Public DCFC charging cost = (Scenario specific incremental EV LDVs + EV on-road freight) * (0.004) * ($ per charger)[20, 21]

Table 9 below shows the national incremental distribution infrastructure cost for each scenario under low, high, and medium chargers costs.

---

[17] Practically all chargers are assumed to be residential L2, and the costs are estimated separately for low, high, and average charger cost.

[18] The factor of 0.06 is based on 60 chargers per 1000 EVs; all chargers are assumed to be of the public L2 type, and the costs are estimated separately based on low, high, and average charger cost

[19] Estimated requirement is between 36 and 79 chargers per 1,000 EVs, depending on community type – e.g., rural, urban. The rounded mid-point is 60 chargers per 1,000 EVs; U.S. Department of Energy, (2017, September) *National Plug-In Electric Vehicle Infrastructure Analysis.* https://www.energy.gov/sites/prod/files/2017/09/f36/NationalPlugInElectricVehicleInfrastructureAnalysis_Sept2017.pdfhttps://www.energy.gov/sites/prod/files/2017/09/f36/NationalPlugInElectricVehicleInfrastructureAnalysis_Sept2017.pdf.

[20] The factor of 0.004 is based on 4 DCFC chargers per 1000 EVs; all chargers are assumed to be of the public DCFC-type and the costs are estimated separately based on low, high, and average charger cost.

[21] Estimated requirement is between 3 and 5 DCFCs per 1,000 EVs, depending on the kW rating of the DCFCs. The mid-point is ~ 4 DCFCs per 1,000 EVs; Electric Power Research Institute, (2014, June) Guidelines for Infrastructure Planning. https://www.epri.com/research/products/000000003002004096https://www.epri.com/research/products/000000003002004096

Table 9: National Incremental Distribution Infrastructure Cost

Charger Cost Case	EV – AEO	EV – 18 MM	EV – 30 MM
Low			
Cost of Residential L2 chargers ($ millions)	12,378	29,683	50,790
Cost of Public L2 chargers ($ millions)	4,132	10,170	17,344
Cost of Public DCFC chargers ($ millions)	3,030	7,458	12,719
Total (all charging infrastructure $millions)	19,540	47,311	80,854
High			
Cost of Residential L2 chargers ($ millions)	24,068	57,716	98,759
Cost of Public L2 chargers ($ millions)	6,198	15,255	26,016
Cost of Public DCFC chargers ($ millions)	4,270	10,509	17,922
Total (all charging infrastructure $millions)	34,536	83,481	142,698
Average			
Cost of Residential L2 chargers ($ millions)	17,675	42,386	72,527
Cost of Public L2 chargers ($ millions)	5,162	12,707	21,669
Cost of Public DCFC chargers ($ millions)	3,746	9,221	15,726
Total (all charging infrastructure $millions)	26,584	64,314	109,923

Table 9 shows that under the EV – 18 MM scenario (with the incremental EV LDVs and on-road freight vehicles from 2019 levels shown in Table 8), utilities will have to make infrastructure investments of about $64 billion by 2030, assuming an average per charger cost level. That estimate could reach $110 billion, if per charger costs are assumed to reach the high level. Several factors could result in upward pressure on realized costs:

- The costs per charger presented here exhibit a wide range and are based on current engineering estimates with only limited real-world experience. As such, they are in today's dollars. While they will be incurred over time with a pace that is commensurate with EV penetration, the cost estimates presented here are conservative in that they do not adjust for normal inflation, which would increase the estimated expenditures in nominal dollars.
- Between 2025 and 2030, the number of EVs grows by 29% per year in the "EV – 18 MM" scenario, and by 44% per year the "EV – 30 MM" scenario. Such high growth rates will translate to rapid growth in demand for infrastructure and logistics/manpower constraints could push up the costs for the fabrication/installation of crucial parts of the infrastructure such as chargers, meters, and distribution transformers.

Transmission Investments Associated with Distribution Investments

In the normal course of business, utilities make investments in generation, transmission, and distribution to meet their service obligations. While generation is open to third parties in some states, transmission and distribution investments will remain in the hands of regulated utilities, and their cost recovery is subject to state regulation of rates.

Transmission investments have the characteristic that they reinforce the overall system, making it hard to allocate costs precisely to those who benefit. Based on timing and location of new EV penetration, there will be transmission investments (including system reinforcements) associated with distribution investments for EV charging infrastructure.

Table 10 shows the investment pattern by investor-owned utilities in generation, transmission, and distribution for 2018 and 2019.

Table 10: Electric Utility Generation, Transmission, and Distribution Investment, $Billions[22]

Sector	2018	2019	Average
Generation	34.0	38.1	36.1
Distribution	37.5	39.0	38.3
Transmission - generation share[23]	10.8	12.7	11.8
Transmission - distribution share[24]	12.0	13.0	12.5
Total	94.3	102.8	98.6

Table 10 shows, based on utility investments in 2018 and 2019, transmission investments are about one-third of the level of distribution investments.[25] Applying this to Table 9, EV distribution infrastructure investments would correspondingly increase total infrastructure investment as shown in Table 11. The infrastructure cost on a per EV basis is driven by the per charger cost and does not vary materially across scenarios. With average charger costs, the cost is $3,800 per EV for distribution costs only and $5,100 per EV when transmission cost is included.

---

[22] Edison Electric Institute (2019, October), *Industry Capital Expenditures with Functional Detail.* https://www.eei.org/issuesandpolicy/Finance%20and%20Tax/EEI_Industry_Capex_Functional_2019.10.16.pdfhttps://www.eei.org/issuesandpolicy/Finance%20and%20Tax/EEI_Industry_Capex_Functional_2019.10.16.pdf

[23] Total transmission expenditures allocated to generation are proportional to: Generation expenditure / (Generation expenditure + Distribution expenditure)

[24] Total transmission expenditures allocated to distribution are proportional to: Distribution expenditure / (Generation expenditure + Distribution expenditure)

[25] 12.5/38.3 = 33% (rounded)

Table 11: Total Infrastructure Investment - Distribution and Transmission

Charger Cost Cases	EV – AEO	EV – 18 MM	EV – 30 MM
Low			
Distribution charging infrastructure, $millions	19,540	47,311	80,854
Associated transmission investment, $ millions	6,448	15,613	26,682
Total, including transmission, $ millions	25,988	62,924	107,535
High			
Distribution charging infrastructure, $millions	34,536	83,481	142,698
Associated transmission investment, $ millions	11,397	27,549	47,090
Total, including transmission, $ millions	45,932	111,030	189,788
Average			
Distribution charging infrastructure, $millions	26,584	64,314	109,923
Associated transmission investment, $ millions[26]	8,773	21,224	36,274
Total, including transmission, $ millions	35,357	85,538	146,197
Distribution investment, (average charger cost, same across scenarios)[27]	**$3,800/EV**		
Distribution and transmission investment, (average charger cost, same across scenarios)[28]	**$5,100/EV**		

Perspective on Charging Infrastructure Investments

In the normal course of business, electric utilities will fund these infrastructure costs by raising electric rates on all customers regardless of whether they own EVs. In addition, spreading these costs among all customers may incentivize utilities to overbuild. Advocates argue that this approach accelerates infrastructure buildout, but it has a substantial impact on all consumers (including non-EV owners). If only EV owners were to bear these infrastructure costs, they would have to pay an additional $9 every time they recharge, assuming a 75-kWh battery. In annual terms, each EV owner would have to pay $500 a year to cover the costs of infrastructure. Socializing these costs among all electric utility customers to accelerate EV infrastructure buildout would mean that EV owners would benefit at the expense of all other electric utility customers.

---

[26] Distribution charging infrastructure cost * 33%

[27] Distribution charging infrastructure cost / 6.9 million EVs

[28] Total cost, including transmission / 6.9 million EVs

Utility Rates and Implications for EV Charging

Rate-setting mechanisms used for utility rates have implications in two important areas for EV charging: 1.) cost shifting across customers, and 2.) practical consequences of standard large-user tariffs for public EV charging.

Because utility costs are allocated to a customer class as part of setting rates, costs such as EV infrastructure costs for residential charging will get allocated to the residential class, absent specific adjustments. If such an allocation occurs, all customers effectively will pay a portion of such infrastructure costs, based on their kWh consumption, regardless of whether they own EVs (or even own any vehicle). This violation of the principle of "beneficiary pays" is referred to as "cost shifting." Put another way, EV owners are subsidized to some degree by non EV-owning customers. EV infrastructure buildouts will cost billions of dollars, making cost-shifting a major subsidy.

Mechanisms to mitigate against cost-shifting could include creation of a separate rate class for EV owners or placing surcharges on EV owners (i.e., not socializing the cost across all customers). Current public policy is headed in the opposite direction, allowing utilities to accelerate investments in EV infrastructure by rate-basing them and recovering costs from all electric utility customers.

Practical Consequences of Electric Rate Structures

Non-differentiated Rates and Residential Charging

With some exceptions, rates for residential customers in the U.S. are largely not differentiated by time-of-day. This means that the per kWh component of rates does not vary by peak and off-peak hours. This approach has been in effect for a long time and is both convenient and transparent, but it provides no economic incentive for the customer to shift electric consumption across the day.

For EV charging this means that customers are likely to plug in their vehicles in the evening hours upon returning from work, frequently exacerbating the peak on the utility system. One common recommendation in EV proceedings before state regulators is to require utility time-of-day pricing and, eventually, real-time pricing. However, "smart" residential charging requires not only the right price signals, but also technology investments and changes in customer behavior. The use of time-of-day pricing (and even real-time) pricing is being advocated for residential customers, not only to make EV charging smarter, but also as a load management tool for other applications (e.g., moving discretionary activities to off-peak-hours).

In the short-term, the realistic scenario is that EV charging will be an uncontrolled load on the system.

Demand Charges and Public Charging

Industrial rates have three components – customer ($/month), demand ($/kW/month), and energy ($/kWh). Because industrial customers have large peaks and serving them requires capital investments in infrastructure commensurate with their peak, a demand charge is broadly consistent with the principle of cost causation ("he who causes a cost, pays for it"). Both public EV charging and residential charging will cause demand peaks and utility infrastructure will have to be sized to serve these peaks.

High peaks raise specific issues for public EV charging rate structure, which has a demand charge unlike residential rates. With a three-part rate, a public charging station with low utilization will have high dollar expenditures for demand charges spread over relatively low kWh usage resulting in a very high average electricity cost per kWh.

As one example, in Florida, if a public charging station took service under Florida Power & Light's (FPL) applicable tariff for comparable customers, they would see rates as ranging from 37 cents to 66 cents per kWh. While this high effective rate is a consequence of the demand characteristics of EVs, it has been the subject of much complaint by EV interests in ongoing proceedings in the state with a push to limit demand charges or fix $/kWh rates for public charging at a lower level without regard to costs they place on the systems. In fact, in response to these complaints, FPL sought approval for a pilot rate fixed at 30 cents/kWh.[29] Disregarding or lowering demand charges for public charging is another way to shift costs from EV users to non-EV users and further distort the fueling marketplace.

---

[29] Florida Power & Light Company, *Petition for Approval of Optional Electric Vehicle Public Charging Pilot Tariffs*, Docket No. 20200170 (2020, June)

Economic Impacts

The economic impact analysis in this study considers the benefits of increased EV infrastructure buildout investments and the additional costs borne by electric utility customers. Broader macroeconomic impacts such as losses in petroleum, biofuels, and auto manufacturing are not part of the analysis.

Distribution and transmission investments made in the utility sector will generate increased economic activity for utilities and their supply chains, such as construction and manufacturing. However, higher costs borne by electric utility customers to repay these investments will decrease real income of households and businesses. Both these impacts are quantified here.

IMPLAN Model Overview

IMPLAN is an input-output or "IO" model[30] of regional and national economies used to determine the impacts from policy changes. IMPLAN is a standard tool with economic impact analysis, and it sees wide applications throughout academia, the public sector, and with consulting firms throughout the world. The data behind the model come from public sources, including the Bureau of Economic Analysis,[31] Bureau of Labor Statistics,[32] and the U.S. Census Bureau.[33]

IMPLAN works by translating direct sales or spending into total impacts. To do this, IMPLAN has a series of "multipliers" describing the linkages between different sectors of the economy. IMPLAN multipliers account for four types of effects, which are summarized here.

- **Direct Impacts** – A direct change in the revenues or expenditures for an industry, such as increased spending on construction related to installing EV infrastructure.
- **Indirect Impacts** – Impacts on suppliers, such as manufacturing firms providing the equipment and materials to produce EV infrastructure and other distribution upgrades. The indirect effect is thus the "supply chain" of an economic sector in IMPLAN.
- **Induced Impacts** – The impact of spending by employees of the direct sector and the indirect suppliers on other sectors. Direct and indirect employees receive paychecks and expend them on the needs of daily life, such as housing and retail products. This provides the induced impacts on the real estate, construction, and retail sectors.
- **Total Impacts** – The sum of the direct, indirect, and induced impacts.

---

[30] Joseph Zamora, "Input-Output Analysis," *Pennsylvania State University*, https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.464.9310&rep=rep1&type=pdfhttps://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.464.9310&rep=rep1&type=pdf

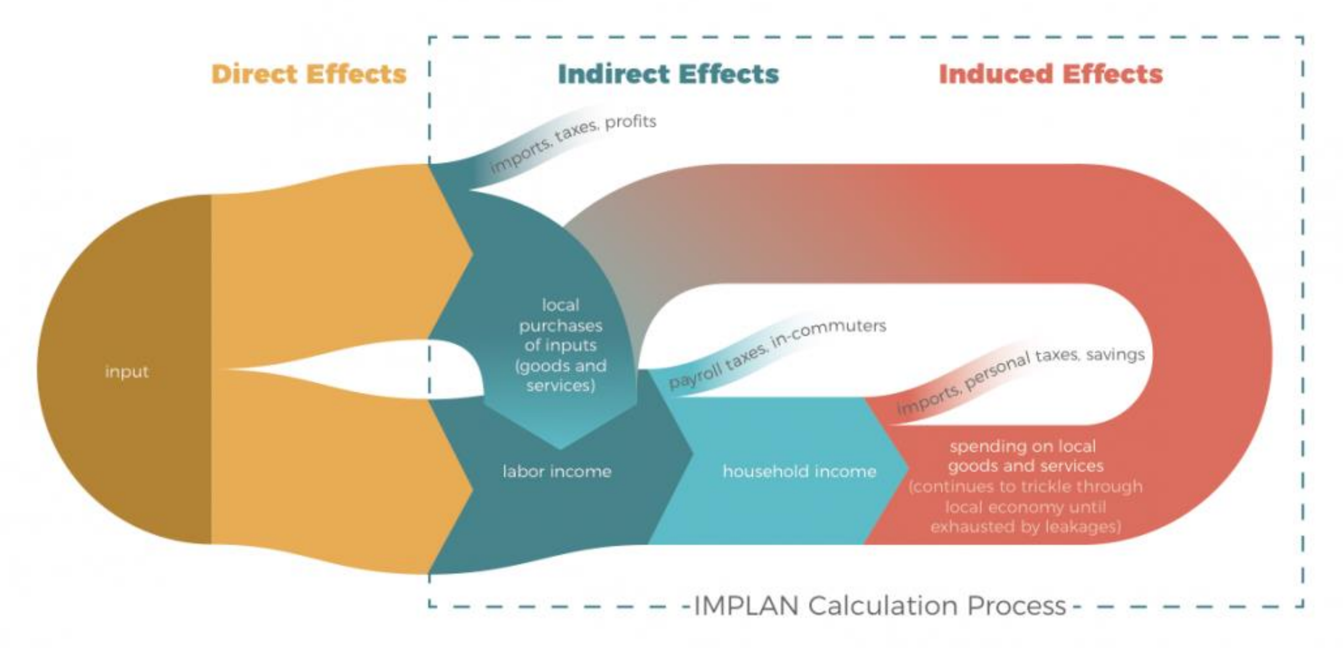
[31] "Regional Economic Accounts," *Bureau of Economic Analysis*, https://www.bea.gov/data/economic-accounts/regionalhttps://www.bea.gov/data/economic-accounts/regional

[32] *U.S. Bureau of Labor Statistics*, https://www.bls.gov/https://www.bls.gov/

[33] *U.S. Census Bureau*, https://www.census.gov/https://www.census.gov/

Figure 2 graphically illustrates the different impacts. Direct effects (in yellow) feed into the indirect supply chain (in blue) before impacting induced spending (in red). Induced spending also triggers a production increase in supply chain sectors, leading to the total impacts.

Figure 2: IMPLAN model diagram



IMPLAN provides the following macroeconomic metrics: economic output,[34] GDP, employment, labor income, federal tax revenues, and state/local tax revenues.

Framework for Distribution and Transmission Spending and Cost Burdens

The positive economic impact on infrastructure spending and the associated cost burden on electric utility customers were modeled in the following manner:

- **Distribution and transmission infrastructure investments** were modeled as an increase in utility spending, which increases the size of the utility sector and, by extension, its indirect suppliers in the construction and manufacturing sectors. Utility and manufacturing sectors tend to be capital-intensive compared to service sectors. That is, they require more capital inputs to production and distribution, which means their productivity may increase while their impact on employment and labor income might be muted.
- **The cost burden on electric utility customers** was modeled as a decrease in households' real incomes. When households face higher costs in the IMPLAN model, they must economize their spending to cover for those higher costs. For instance, if a household's utility bills are higher in the future than currently projected, households must reduce their spending on some other priorities (e.g., travel or entertainment) to make up the difference.

---

[34] Also called business sales.

This study assumed that the commercial and industrial customers would pass their higher costs along to their residential customers in the model. That is, if commercial customers such as retail stores face higher electric utility bills due to EV infrastructure costs, they pass their higher lighting and air conditioning costs along to their customers in the form of higher prices, which reduces the real incomes of households.

IMPLAN Modeling Results

The net effect reflects the sum of the positive impact of the infrastructure spend versus the negative impact of higher electricity rates on consumers' real incomes. Table 12 below shows the net impact for each of the metrics discussed above for a $1 billion infrastructure spend.

Table 12: Impact of $1 billion Distribution and Transmission Spend

Macroeconomic Metric	Impact of $1 billion spend
GDP, $ millions	-29
Output, $ millions	245
Labor income, $ millions	-280
Employment, number of jobs	-7,886
Federal tax receipts, $ millions	-35
State tax receipts, $ millions	85

IMPLAN is a linear model, which implies the impacts can scale up or down depending on the projected levels of spending in a scenario. The annualized infrastructure spending estimates developed earlier (under the average charger cost case) are in Table 13.

Table 14 shows the economywide impact for the three study scenarios, again assuming average charger costs for each.

Table 13: Annualized Infrastructure Spend with Average Charger Costs

Cost item	EV – AEO	EV – 18 MM	EV – 30 MM
Distribution charging infrastructure, $billions	26.6	64.3	109.9
Associated transmission investment, $ billions	8.8	21.2	36.3
Total, including transmission, $ billions	35.4	85.5	146.2
Per year spend in each of 10 years, including transmission, $ billions	3.5	8.6	14.6

Table 14: Economy-wide Impact of EV Infrastructure Spending by Scenario

Macroeconomic Metric	EV – AEO	EV – 18 MM	EV – 30 MM
GDP, $ millions	-102	-247	-424
Output, $ millions	866	2,091	3,582
Labor income, $ millions	-992	-2,393	-4,100
Employment, number of jobs	-27,886	-67,302	-115,298
Federal tax receipts, $ millions	-125	-300	-515
State tax receipts, $ millions	299	723	1,238

As Table 14 shows, the impact of the cost burden of infrastructure expansion is negative for GDP, labor income, employment, and federal tax receipts. Labor income falls as the cost of the infrastructure is passed through in electric utility rates. In the “EV – 30 MM” scenario, labor income falls by close to $4.1 billion. In the same scenario, employment falls by 115,300 jobs. The negative impacts on the economy are offset, in part, by the stimulus provided by infrastructure expansion leading to an increase in sales (or output) and an increase in state tax receipts (which are tied significantly to sales).

.

Appendix – State Level Estimates

Using the same approach as used for national estimates, state level infrastructure cost was estimated using per charger costs. At this stage, the per charger estimates do not allow for a meaningful distinction between states. Accordingly, the per charger costs are the same as used in the national estimates. A 2017 U.S. Department of Energy study[35] developed state level projections of EV penetration, which were used for four states of interest and are shown in Table 15, Table 16 and Table 17.

Table 15: State-Level Infrastructure Cost for the EV – AEO Scenario

Data Item	**FL**	**MN**	**NJ**	**PA**
Market-Share	5.60%	1.50%	2.20%	3.20%
2030 Incremental EV Light Duty Stock, millions	0.39	0.11	0.15	0.22
2030 Incremental EV On-road Freight, millions	0.0006	0.0002	0.0002	0.0003
2030 Total Incremental EV's (LD + On-road Freight), millions	0.39	0.11	0.15	0.22
2030 Public L2 chargers[1/]	23214	6324	9291	13035
2030 Public DCFC chargers[1/]	1548	422	619	869
Low Charger Cost				
Cost of Residential L2 chargers ($ millions)	695	189	278	390
Cost of Public L2 chargers ($ millions)	232	63	93	130
Cost of Public DCFC chargers ($ millions)	170	46	68	96
Total (all charging infrastructure, $ millions)	1098	299	439	616
High Charger Cost				
Cost of Residential L2 chargers ($ millions)	1354	369	542	760
Cost of Public L2 chargers ($ millions)	348	95	139	196
Cost of Public DCFC chargers ($ millions)	240	65	96	135
Total (all charging infrastructure, $ millions)	1942	529	777	1091
Average Charger Cost				
Cost of Residential L2 chargers ($ millions)	994	271	398	558
Cost of Public L2 chargers ($ millions)	290	79	116	163
Cost of Public DCFC chargers ($ millions)	210	57	84	118
Total (all charging infrastructure, $ millions)	1495	407	598	839

1/ Basis: 60 public L2 chargers; 4 DCFC per 1000 EVs

---

[35] U.S. Department of Energy (2017, September), *National Plug-In Electric Vehicle Infrastructure Analysis*

Table 16: State Level Infrastructure Costs for the EV – 18 MM Scenario

Data Item	FL	MN	NJ	PA
Market-Share	5.60%	1.50%	2.20%	3.20%
2030 Incremental EV Light Duty Stock, millions	0.93	0.25	0.37	0.52
2030 Incremental EV On-road Freight, millions	0.026	0.007	0.01	0.015
2030 Total Incremental EV's (LD + On-road Freight), millions	0.95	0.26	0.38	0.53
2030 Public L2 chargers[1/]	57,139	15,565	22,869	32,085
2020 Public DCFC chargers[1/]	3,809	1,038	1,525	2,139
Low Charger Cost				
Cost of Residential L2 chargers ($ millions)	$1,668	$454	$667	$936
Cost of Public L2 chargers ($ millions)	$571	$156	$229	$321
Cost of Public DCFC chargers ($ millions)	$419	$114	$168	$235
Total (all charging infrastructure, $ millions)	$2,658	$724	$1,064	$1,493
High Charger Cost				
Cost of Residential L2 chargers ($ millions)	$3,243	$883	$1,298	$1,821
Cost of Public L2 chargers ($ millions)	$857	$233	$343	$481
Cost of Public DCFC chargers ($ millions)	$590	$161	$236	$332
Total (all charging infrastructure, $ millions)	$4,690	$1,278	$1,877	$2,634
Average Charger Cost				
Cost of Residential L2 chargers ($ millions)	$2,381	$649	$953	$1,337
Cost of Public L2 chargers ($ millions)	$714	$194	$286	$401
Cost of Public DCFC chargers ($ millions)	$518	$141	$207	$291
Total (all charging infrastructure, $ millions)	$3,613	$984	$1,446	$2,029

1/ Basis: 60 public L2 chargers; 4 DCFC per 1000 EVs

Table 17: State-Level Infrastructure Cost for the EV – 30 MM Scenario

Data Item	FL	MN	NJ	PA
Market-Share	5.60%	1.50%	2.20%	3.20%
2030 Incremental EV Light Duty Stock, millions	1.59	0.43	0.63	0.89
2030 Incremental EV On-road Freight, millions	0.04	0.01	0.02	0.02
2030 Total Incremental EV's (LD + On-road Freight), millions	1.62	0.44	0.65	0.91
2030 Public L2 chargers[1/]	97,443	26,544	39,000	54,717
2020 Public DCFC chargers[1/]	6,496	1,770	2,600	3,648
Low Charger Cost				
Cost of Residential L2 chargers ($ millions)	$2,854	$777	$1,142	$1,602
Cost of Public L2 chargers ($ millions)	$974	$265	$390	$547
Cost of Public DCFC chargers ($ millions)	$715	$195	$286	$401
Total (all charging infrastructure, $ millions)	$4,543	$1,237	$1,818	$2,551
High Charger Cost				
Cost of Residential L2 chargers ($ millions)	$5,548	$1,511	$2,221	$3,116
Cost of Public L2 chargers ($ millions)	$1,462	$398	$585	$821
Cost of Public DCFC chargers ($ millions)	$1,007	$274	$403	$565
Total (all charging infrastructure, $ millions)	$8,017	$2,184	$3,209	$4,502
Average Charger Cost				
Cost of Residential L2 chargers ($ millions)	$4,075	$1,110	$1,631	$2,288
Cost of Public L2 chargers ($ millions)	$1,217	$332	$487	$684
Cost of Public DCFC chargers ($ millions)	$884	$241	$354	$496
Total (all charging infrastructure, $ millions)	$6,176	$1,682	$2,472	$3,468

1/ Basis: 60 public L2 chargers; 4 DCFC per 1000 EVs

References

Argonne National Laboratory. (2020, January). *U.S. Plug-in Electric Vehicle Sales by Model.* Retrieved from https://afdc.energy.gov/: https://afdc.energy.gov/data/10567

Atlantic City Electric Company. (2018, February 22). *Voluntary Program for Plug-In Vehicle Charging, Docket No. EO18020190.* Retrieved from atlanticcityelectric.com: https://www.atlanticcityelectric.com/Documents/ACE%20-%20Petition%20-%20PIV%20Program%20-%20FINAL%20-2-22-2018.pdf

Atlas Public Policy. (2019, June). *Assessing the Business Case for Hosting Electric Vehicle Charging Stations in New York State Final Report.* Retrieved from https://www.atlasevhub.com/: https://www.atlasevhub.com/wp-content/uploads/2019/09/19-31-Business-Case-for-Hosting-Charging-Stations-for-publication-3.pdf

Avista Corp. (2019, October 18). *Electric Vehicle Supply Equipment Pilot Final Report.* Retrieved from myavista.com: https://www.myavista.com/-/media/myavista/content-documents/energy-savings/electricvehiclesupplyequipmentpilotfinalreport.pdf?la=en

Department of Public Service New York. (2020, January 13). *Department of Public Service Staff Whitepaper Regarding Electric Vehicle Supply Equipment and Infrastructure Deployment.* Retrieved from www.dps.ny.gov: http://documents.dps.ny.gov/public/Common/ViewDoc.aspx?DocRefId={652C94FC-7669-4578-9B89-70EC65AC9C55}

DNV GL (2020, February), DER Grid Impacts Analysis, Prepared for California Public Utility Commission

Duquesne Light Company. (2020, April 2). *EV ChargeUp Pilot Annual Report January 2019 – February 2020.* Retrieved from http://www.puc.state.pa.us/: http://www.puc.state.pa.us/pcdocs/1659691.pdf

Fresh Energy, NRDC, Sierra Club, and MCEA. (2017, July 27). *Efilings, Docket # 17-879, Document ID, 20187-145282-01.* Retrieved from https://www.edockets.state.mn.us/: https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={80FFDC64-0000-CF18-AE69-6C936C279BF4}&documentTitle=20187-145282-01

MJ Bradley & Associates, LLC. (2017, December 6). *Accelerating Investment in Electric Vehicle Charging Infrastructure.* Retrieved from mjbradley.com: https://www.mjbradley.com/sites/default/files/Ceres_PEVinfraAnalysis_120617.pdf

Muratori, M. (March 2018). *Electrification Opportunities in the Transportation Sector and Impact of Residential Charging.*

Otter Tail Power Company. (2020, January 31). *Initial Filing--Electric Vehicle Charging & Infrastructure, Document ID 20201-159953-01.* Retrieved from https://www.edockets.state.mn.us/: https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={108AFD6F-0000-CA19-940F-B2FE49F0BFEE}&documentTitle=20201-159953-01

PSEG. (2018, October 11). *Clean Energy Future (CEF) Filings, CEF-EVES Docket # E018101111.* Retrieved from https://nj.pseg.com/: https://nj.pseg.com/aboutpseg/regulatorypage/-/media/6EA1F476B43F4BCBAB7D5F7A46E19DF7.ashx

Rocky Mountain Institute, (2019),Reducing EV Charging Infrastructure Costs

Southern California Edison Company. (2020, June 1). *Southern California Edison Company (U 338-E) Charge Ready Pilot Program Report.* Retrieved from https://www.sce.com/: http://www3.sce.com/sscc/law/dis/dbattach5e.nsf/0/1DF31138E47AF8018825857A0067B759/$FILE/A1410014-SCE%20Quarterly%20Charge%20Ready%20Pilot%20Program%20Report%202020Q1.pdf

Xcel Energy. (2018, October 12). *Initial Filing--Petition for Approval of Electric Vehicle Pilot Programs, Document ID 201810-146991-01.* Retrieved from https://www.edockets.state.mn.us/: https://www.edockets.state.mn.us/EFiling/edockets/searchDocuments.do?method=showPoup&documentId={20487866-0000-C91D-8A2C-DC644D11E81D}&documentTitle=201810-146991-01