Electric Vehicle Supply Equipment 101: Types and Levels of Charging

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This research guide was compiled from two memos written on electric vehicle charger types and levels. It addresses economic costs and sustainability impacts and was written to inform ACC's Sustainability Office on future options for public transit electrification and possibilities for public consumer charging stations.

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Executive Summary and Glossary

Two types of charging dominate the electric vehicle markets: inductive and conductive. Inductive and conductive charging are services that have been expanding rapidly since their introduction to public transit. Both charge electric buses without exposed wires, are capable of charging while en route, and, depending on the system, do not see significant cost increases over traditional charging methods. Both methods are safe for passengers and drivers while maintaining efficient charging rates with minimal loss to heat. Inductive charging has the additional advantages of not requiring metal-to-metal contact, reducing bus weight, and not requiring cooling systems.

Within the electric vehicle industry, types can be further subdivided by level of charger - that is, the speed at which a charger performs. Several key considerations have been documented in research, summarized here:

- Level 1, 2, and 3 chargers scale up in cost exponentially; level 2 chargers remain the best middle ground for affordability and ease of installation
- Equity must be considered in electric vehicle supply equipment (EVSE, or EV charging stations) to promote the growth of EV accessibility
- EVSE installation costs are 55-60% labor, 30-35% materials, 5% permits, and 5% tax for private entities
- EVSE equipment lasts about 10 years and almost universally uses J1772 charging ports

Types of Charging

Term	Definition
Inductive charging	A method of charging portable electric batteries without a direct connection such as a wire or outlet. Induction coils in each device create an electromagnetic field which passes power from the charging coil to the receiving coil, which then transfers the power to the battery
Conductive charging	A method of charging portable electric batteries which involves a direct, but wireless connection between a battery and its charger. Power passes from a charging board to a receiver in the device to be charged. This method requires a metal-to-metal connection between devices.
Wired charging	A method of charging portable electric batteries which involves a direct, wired connection between a battery and its charger. This is the standard form of charging in EVs.

Inductive Charging

Inductive charging is a wireless power transfer method which has recently been commercialized in public transit contexts.The process involves a vehicle with a receiving coil and a charging coil coming within six meters. The coils generate an electromagnetic field which transfers power from the charging coil to the receiving coil, which then moves the electricity into the battery.

Inductive charging has only recently been transitioned to larger scale use in buses and vehicles. Inductive charging is safe in two different respects over traditional, cabled charging. It improves system operational safety because there are no exposed cables or power outlets.[1] Risks of magnetic field interference are also minimal; the fields generated by commercial induction chargers are well within limits set by the Federal Communications Commission, International Electrical and Electronics Engineer Standards Association, and the International Commission on Non-Ionizing Radiation Protection.[2]

Inductive charging is efficient, to a point. Inductive charging stations achieve 90%+ power transfer efficiency, with 98% of transmitted energy reaching the secondary coil on the bus.[3] This efficiency rating is buoyed by a close proximity between charging pads; while induction can occur over six meters, the closer the pads are the more efficient the transfer. Smaller coils are also more efficient.[4] Inductive chargers also do not require wire cooling, so less energy is lost to heat; this can be further reduced by using multiple charging modules to reduce overall thermal energy loss.[5]

Inductive charging also makes significant strides in battery weight, which reduces overall wear-and-tear on buses. Research shows that inductive batteries are 27-44% smaller than other EV batteries, which leads to a 12-16% reduction in bus weight. This further leads to a 7% decrease in battery-to-wheel energy consumption and, in a vehicle's life cycle, lowered greenhouse gas emissions and energy consumption.[6]

Induction charging is also cost efficient. Simulation analyses showed that the use of wireless charging vehicles reduced the number of vehicles required in a fleet by up to 50%.[7] Wide-scale deployment of inductive charging reduces investment costs per vehicle and mitigates adoption barriers to electric vehicles in the wider transit system.[8]

The most well known inductive bus system in the United States is the Antelope Valley Transit Authority. Over the course of 2016 and 2017, ATVA purchased more than 30 electric buses, 87 charging

[1] Brecher and Arthur 2014
[2] Doss, H.M.
[3] Doss, H.M.; Brecher and Arthur 2014
[4] Ibid.
[5] Kane 2020
[6] Bi et al. 2015; Mohamed, Wood, and Meintz 2020
[7] Kane 2020; Bi et al. 2015
[8] Bi et al. 2015

stations, and a 1.5 MW backup generator.[9] In July 2021, ATVA announced that it was purchasing 28 WAVE inductive receptors for $2.22 million for a cost of ~$79,000 per charger. These chargers allow buses which roll over the pad to wirelessly couple and charge at stops. ATVA uses BYD brand electric buses.[10] The fleet now consists of more than 70 electric buses. The buses cost an estimated $78.6 million, or ~$925,000 per bus, though cost depends significantly on bus size.[11]

Conductive Charging

Conductive charging is another form of wireless charging. Unlike inductive charging, it requires metal-to-metal contact between the charger and battery.[12]

Conductive charging is cheaper to install because of its relative simplicity, but it suffers from longer charging times because of the time it takes for a connection to be made between a vehicle and the charging station.

Conductive charging also uses physically exposed machines, which makes it more vulnerable to wire theft and third-party tampering. It is completely safe for use: conductive chargers detect when human or unintended metal contact is made with the device and shut off.[13]

Conductive charging is in wider use than inductive charging. MARTA, Atlanta's public transit system, uses conductive charging at three locations for its buses. Their system includes an en route fast-charging station at East Lake Rail Station as well as two depot stations at Laredo Maintenance and Browns Mill Maintenance. About 14,000 passengers use MARTA's electric buses each week.[14]

[9] Antelope Valley Transit Authority 2018
[10] Drake, Julie 2021
[11] McCoy and Maze-Rothstein 2020
[12] Seattle Today 2020
[13] Ibid.
[14] MARTA 2020

Levels of EV Charging

Ballpark EVSE Unit and Installation Costs

EVSE Type	EVSE Unit* Cost Range (single port)	Average Installation Cost (per unit)	Installation Cost Range (per unit)
Level 1	$300-$1,500	not available	$0-$3,000** *Source: Industry Interviews*
Level 2	$400-$6,500	~$3,000 *EV Project (INL 2015b)*	$600-$12,700 *EV Project (INL 2015b)*
DCFC	$10,000-$40,000	~$21,000 *EV Project (INL 2015d)*	$4,000-$51,000 *EV Project (INL 2015d) and (OUC 2014)*

[15]

Table 2. Per charger public and workplace charger hardware cost.[16]

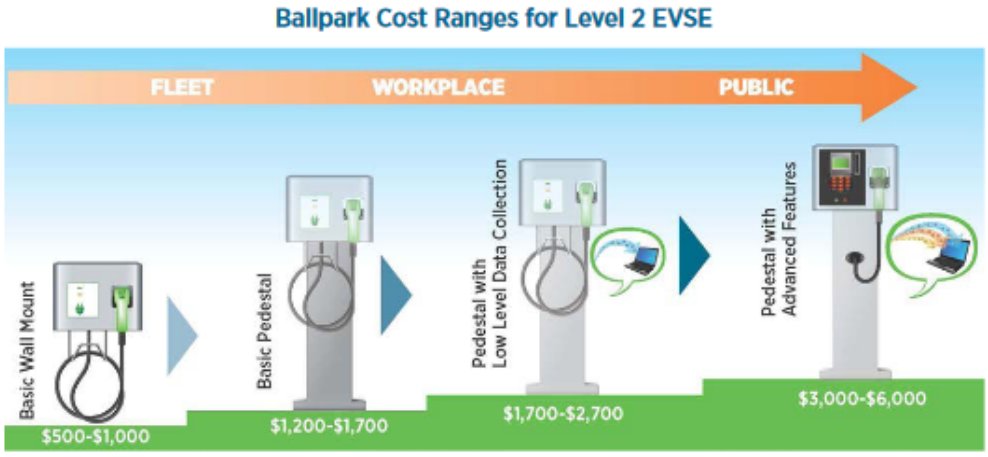
Level	Type	Chargers per pedestal	Per-charger cost	Total charger cost
Level 1	Non-networked	1	$813	$813
Level 1	Non-networked	2	$596	$1,192
Level 2	Non-networked	1	$1,182	$1,182
Level 2	Non-networked	2	$938	$1,876
Level 2	Networked	1	$3,127	$3,127
Level 2	Networked	2	$2,793	$5,586
DC Fast	Networked 50kW	1	$28,401	$28,401
DC Fast	Networked 150 kW	1	$75,000	$75,000
DC Fast	Networked 350 kW	1	$140,000	$140,000

There are three common levels of EV charging. **Level 1** charging is the slowest and most commonly available. It corresponds to a regular outlet at 110-120 volts (12-16 amps continuous), and is the standard for home charging.[17] level 1 chargers add about 4-5 miles of charge per hour and cost around $300-$1,500 dollars for a station. Parts and labor for installation can range from $0 to $3,000, depending on the station type and the ease of electrical panel access.[18]

Level 2 chargers are 220-240 volts (16-48 amps continuous), adding 25 miles of range per hour of charging.[19] Level 2 chargers are available for home installation, but are most commonly seen in non-

[15] New West Technologies, LLC 2015
[16] Nicholas 2019
[17] New West Technologies, LLC 2015
[18] "How Much Does an Electric Car Charging Station Installation Cost?"
[19] New West Technologies, LLC 2015

residential charging stations. The station itself costs between $400-$6,500, while parts and labor range from $600-$12,700.[20] Station costs at level 2 vary significantly based on the mount:



Level 3 chargers, also known as DCFC, DC fast, CHAdeMO, or direct current chargers, are the most expensive and fastest EV chargers. At a minimum of 400 volts (600+ amps continuous), level 3 chargers add 150 miles per hour of charging.[21] The station itself costs $10,000-$40,000 at current market rates, and parts and labor for installation cost $4,000-$50,000. Level 3 chargers often require special installations and modifications to the electrical system to function at capacity. For most groups looking to install EV chargers for public use, these costs are prohibitive in all but the most extreme circumstances; this may change as technology improves and level 3 chargers become cheaper.[22]

Installing EV Chargers

The costs for EV charger installation vary on several factors, the most important of which are ease of access to the electrical panel and style of charger. In general, pedestal-mounted chargers cost more than wall-mounted or outlet-based chargers. Installation costs are 55-60% labor, 30-35% materials, 5% permits, and 5% tax.[23]

Various factors must be considered to estimate installation. The primary charge is connecting a station to electrical service, which can involve trenching or boring for a conduit from the transformer, modifying the electrical panel for dedicated circuits, locating chargers on levels above or below electrical service, and upgrading electrical equipment. ADA requirements, traffic protection, signage, lighting, permitting, inspecting, and engineering review are also installation cost requirements.[24] Further, warranties and land purchases can factor into final costs for EV charging stations.

Generally, level 1 outlet-based chargers cost between $200 and $500 to upgrade an outlet to 120V capacity. In a parking garage, hardwiring to the electrical service can cost between $300 to $1,000,

[20] "How Much Does an Electric Car Charging Station Installation Cost?"
[21] New West Technologies, LLC 2015
[22] "How Much Does an Electric Car Charging Station Installation Cost?"
[23] New West Technologies, LLC 2015
[24] Ibid.

assuming the charger is within 50ft of electricity. Pedestal-mounted chargers cost $1,000 to $3,000, also assuming they are within 50ft of electrical service.[25]

Level 2 chargers cost at minimum $2,000 to install. For wall-mounted units, $2,000 is required to wire into the electrical service assuming 50ft distance. For pedestal units, costs go up to $3,000-$3,500. The minimum installation cost was $600, while the maximum was $12,660. Notably, workplace installation of level 2 EV charger is less than public installation due to the distance from electrical service being lower, number of stations being higher, and ability of private institutions to ignore some accessibility requirements.[26]

Table 3. Installation costs per level 2 public charger by chargers per site[27]

Chargers per site	**1**	**2**	**3-5**	**6+**
Labor	$1,544	$1,827	$1,657	$1,416
Materials	$1,112	$1,039	$1,272	$874
Permit	$82	$62	$59	$38
Tax	$96	$89	$110	$75
Total	$2,836	$3,020	$3,090	$2,305

Level 3 chargers have many of the same installation costs as level 2 chargers with the added costs of upgrading electrical service to handle upwards of 600 amps continuously. This significantly increases installation cost, with some level 3 chargers requiring $50,000 to install.

Table 4. Installation costs per DC fast charger by power level and chargers per site.

	50 kW				**150 kW**				**350 kW**			
	1 charger per site	**2 chargers per site**	**3-5 charger per site**	**6-50 chargers per site**	**1 charger per site**	**2 chargers per site**	**3-5 chargers per site**	**6-20 chargers per site**	**1 charger per site**	**2 chargers per site**	**3-5 chargers per site**	**6-10 chargers per site**
Labor	$19,200	$15,200	$11,200	$7,200	$20,160	$15,960	$11,760	$7,560	$27,840	$22,040	$16,240	$10,440
Materials	$26,000	$20,800	$15,600	$10,400	$27,300	$21,840	$16,380	$10,920	$37,700	$30,160	$22,620	$15,080
Permit	$200	$150	$100	$50	$210	$158	$105	$53	$290	$218	$145	$73
Taxes	$106	$85	$64	$42	$111	$89	$67	$45	$154	$123	$92	$62
Total	$45,506	$36,235	$26,964	$17,692	$47,781	$38,047	$28,312	$18,577	$65,984	$52,541	$39,097	$25,654

[28]

Recurrent/Annual Costs of EV Chargers

Operation and maintenance costs for EV chargers are fairly low relative to the cost of a station and installation. Charges include electricity consumption, a network subscription, billing transaction costs, repairs, and preventative and corrective maintenance. For a level 1 charger, consumption comes out

[25] Smith 2016
[26] The EV Project 2015
[27] Smith 2016
[28] Smith 2016

to be $110 per year.[29] Warranties for any level are approximately $400, though this can vary significantly.[30]

The expert-estimated lifespan of an EVSE is 10 years. Over the course of an EVSE's lifespan, level 1 and 2 chargers require the least maintenance. This can include cord replacement, technician troubleshooting, and manual reset of software. Level 3 EVSEs require ongoing maintenance because of additional cooling systems, filters, and higher-grade components. One estimate places the annual cost of maintenance of an EVSE unit at $25-$50.[31]

Table 1. 10-Year Life-Cycle and Electricity Costs for PEV Charging Stations

Station Type (10 kWh's/day per vehicle)	Per Session Life-Cycle Costs			
	Fully Utilized		Underutilized	
	Life-Cycle	Electricity Cost[1]	Life-Cycle	Electricity Cost[1]
AC Level 1 – R	*$1.79*	*$1.28*	*$1.79*	*$1.28*
AC Level 1 – C	$1.53	$1.00	$1.53	$1.00
AC Level 1 – D	$1.79	$1.29	$1.79	$1.29
AC Level 2 – C – No fee	$1.32	$1.00	$2.60	$1.00
AC Level 2 – C – Fee	$2.24		$6.28	
AC Level 2 – D – No fee	$1.67	$1.39	$5.07	$3.77
AC Level 2 – D – Fee	$2.59		$8.75	
DC Level 2 – D	$2.39	$1.26	$30.15	$11.16
DC Level 2 – T	$2.75		$35.93	

R – residential, C – commercial non-demand, D – commercial demand, T – commercial demand with new transformer.
No fee – no annual or per payment processing fees, Fee – annual or per payment processing fees
Fully utilized: AC Level 1 – 1 vehicle per day, AC Level 2 – 4 vehicles per day, DC Level 2 – 16 vehicles per day
Note: [1] – dollar values represent year 1 actual cost

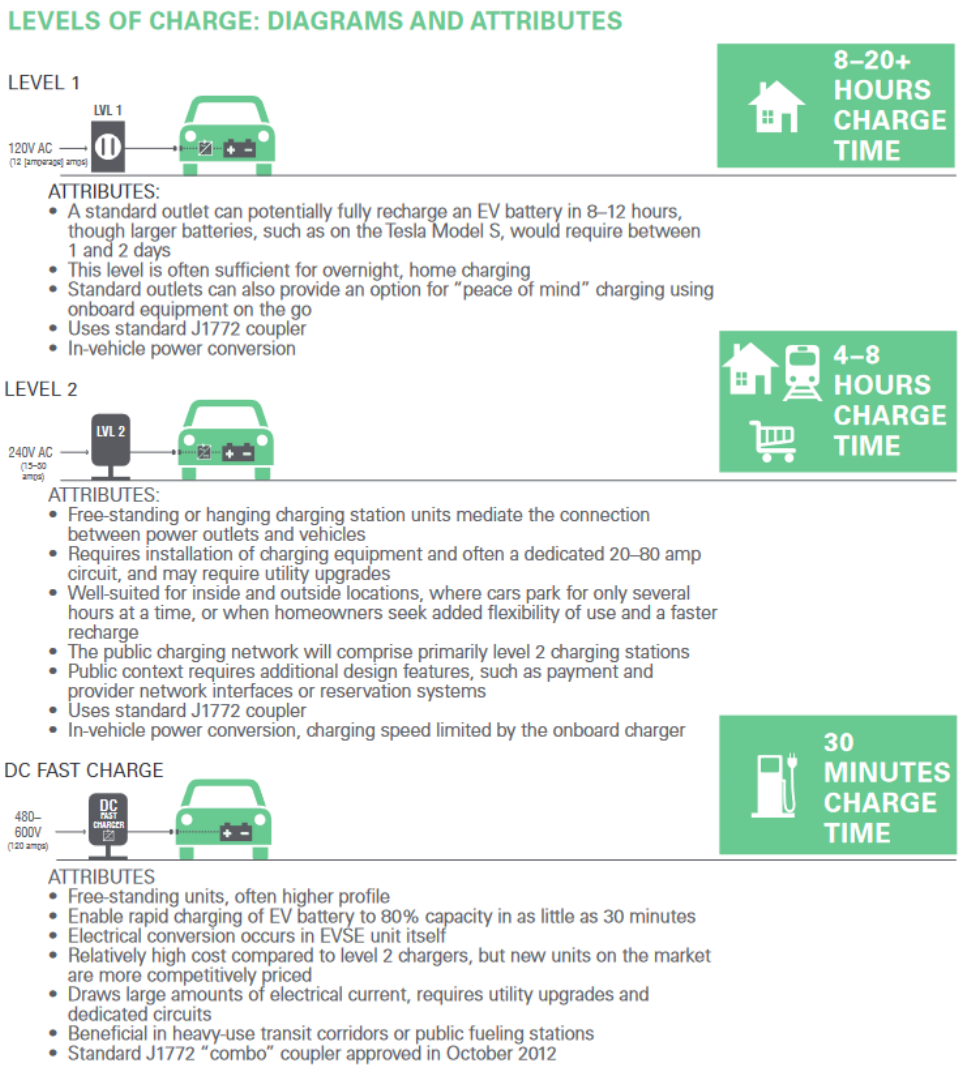
[32]

[29] The EV Project 2015

[30] "Charging Infrastructure Operation and Maintenance"

[31] "Plug-In Electric Vehicle Handbook for Public Charging Station Hosts"

[32] Kettles and Raustad 2017



Attributes of EVSEs and Plug Types

Above is a resource prepared by WXY Architecture + Urban Design for the New York State Energy Research and Development Authority which quickly lays out the differences between electric vehicle supply equipment (EVSE). The most important attribute to note between chargers is the standardization of the J1772 coupler, with the additional combo coupler for DC charging.[33] Two types which are not included in this are the Tesla Supercharger and CHAdeMO outlets, which are for Tesla and Japanese EV level 3 charging.[34]

[33] WXY Architecture + Urban Design 2012

[34] "All relevant charging cable and plug types"

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