Electric vehicles and the charging infrastructure: a new mindset?

“On-the-go” charging is key to EV growth

In the next decade, the number of electric vehicles (EVs) on our roads will likely rise substantially, and we believe the bulk of the charging of these vehicles will take place at home. But charging away from home or a workplace will also be key to support EV growth. Such “on-the-go” charge-ups will also need to be as easy and convenient as refueling an internal combustion engine (ICE) vehicle today.

While EVs account for less than 2% of new vehicle registrations in the US, and much less than 1% of all vehicles on the road today (according to IHS Markit), the underlying economics of EV ownership are improving. State and federal regulators are incentivizing adoption, signaling that EV penetration will likely increase steadily over the next decade and beyond. The Biden administration has pledged to extend EV tax credits. And California—often a bellwether for other states—has moved to ban new ICE cars from 2035. We expect that, by then, EV ownership will be economically viable for most drivers (even without tax breaks or other incentives).

So how will the EV infrastructure support the developing fleet? Today’s automobile culture is supported today by an estimated 135,000 outlets with some 1.4 million pumps, estimates the National Petroleum News. This network balances the competing demands of low cost and efficiency, locational convenience and capacity utilization. The result is that most motorists in most situations can easily find a competitively priced gas station and not wait in line for an open pump. We expect similar dynamics will shape the emerging network of EV-charging stations.

Let’s assess the underlying economics of charging currently, and how it could—or will need to—change in the future to support the growing US EV fleet.

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EV charging—A primer

EV chargers are defined by the amount of energy delivered to the vehicle's battery per unit of time. There are four "levels," with Level 4 the fastest. As the table below shows, different levels of chargers have very different power ratings and charge times for typical EVs.

Charger level	Typical power rating (KW)	Example installation	Charge time for 100 miles of range (1,2)
1	1 KW	• Standard electrical outlet in a residential garage	20 hours
2	5 KW	• Specialized domestic charging apparatus (often sold as optional extra with vehicle or supplied by specialist third parties) • Workplace parking lot installations • Many public access charge points at retail stores, parking lots etc.	4 hours
3	80 KW	• Specialized fast chargers designed for users on the go	40 mins
4	120 KW	• Ultra-fast chargers for users on the go • To-date installed by vehicle OEM as proprietary support for their customers/owners	25 mins

Note (1): Typical EV fuel economy runs around 200 KWH per tonne-mile, so a typical 2.5 tonne vehicle requires about 50 KWH for a 100-mile run. EV manufacturers typically optimize vehicles to achieve the best possible fuel economy within other constraints (number of seats, performance, etc.)

Note (2): At very high powers, the limitation on charging rate may become the vehicle's battery management system rather than the charger's capacity.

Not surprisingly, the capital and operating costs of higher-capacity chargers (excluding the electrical power delivered) is higher than those of lower-capacity chargers. Level 1 chargers—like a residential 110-volt outlet—are nearly free to operate. Level 3 and 4 chargers, however, are more expensive and complex.

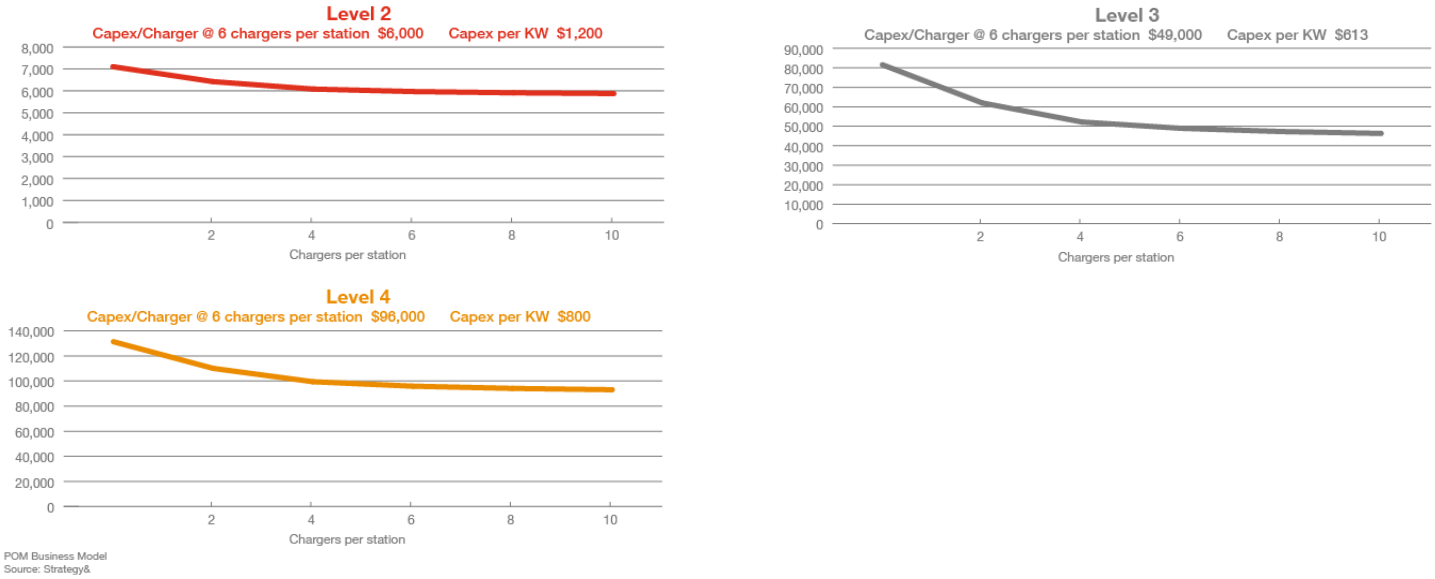
So how should we think about charging costs, and what are the implications of these costs? In particular, will consumers be willing to pay a premium for faster, high-level chargers? To examine this, let's look at the costs of building and operating charging networks.

Capital costs

Capex for a charger consists of the charging equipment itself (similar to a gas pump) plus any required upgrades to the local electricity grid, land, civil works, etc. Most capital cost comprises the charging hardware itself. There are some economies of scale, but these peak as the station reaches four to six chargers, with capital cost per charger declining slowly as the overall size and capacity of the station increases. While Level 2 chargers are relatively less costly to build (with only a 5 KW capacity) on a per-KW basis, they're actually more expensive than Level 3 and 4 chargers.

EV charging stations reach minimum efficient scale at 4–6 charger points

Capital expenditures per charger by level and station format ($ per charger)

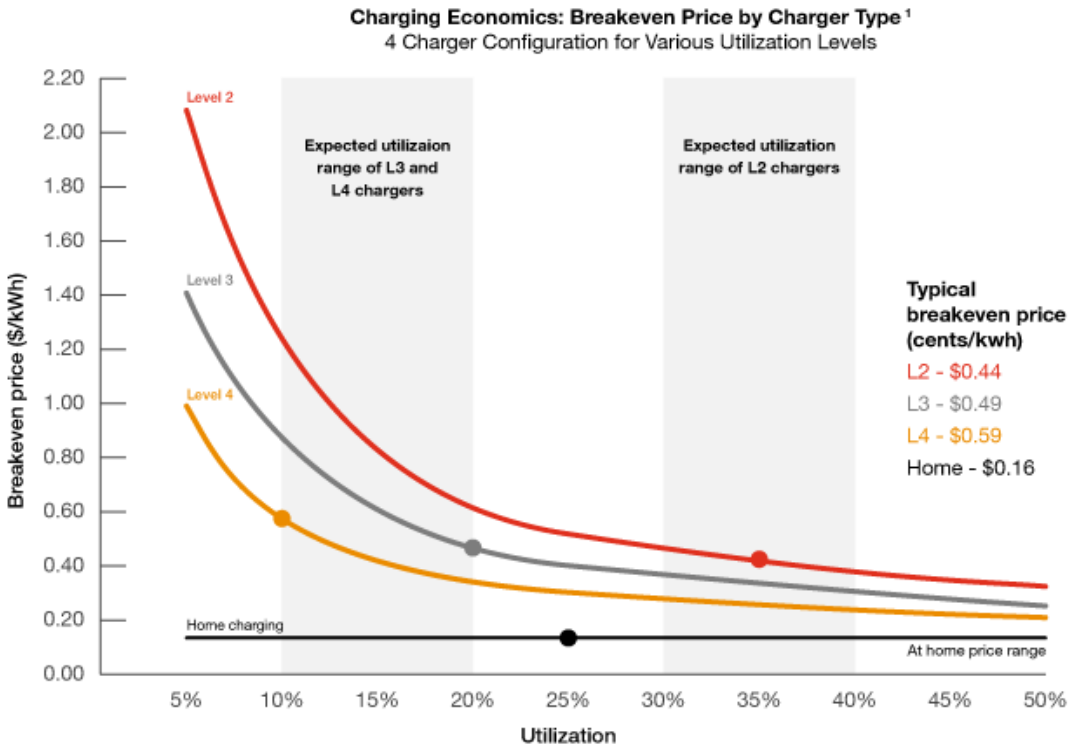


POM Business Model
Source: Strategy&

Operating costs

Labor costs for charging stations are quite low. They're typically unattended, self-service and require less maintenance than gas pumps. However, charging locations connected to a local electricity grid are subject to "capacity charges" used to offset the costs of utility upgrades needed to accommodate them. Capacity charges are linked to the highest expected load a given charging station may require. In principle, then, a Level 4 station could have twice the peak load of a Level 2 station—and a higher capacity charge. This capacity charge is fixed and recurring (typically monthly), regardless of whether or not the peak load is reached in any given month.

Higher level chargers have higher costs than lower level ones—unless utilization is very high



1. All-in breakeven price is selling price required to earn a 10% return on capital invested with a wholesale power cost of $0.16 per Kwh
Source: Strategy&

This cost structure raises four implications:

Modest returns-to-scale

There are relatively modest returns-to-scale at the location level. That is, a higher capacity station (one with more chargers) is not inherently lower cost (per KWH delivered) than a lower capacity station. Today, the average number of chargers per location is about eight. These networks will likely evolve to more numerous—and hence more widespread—smaller-capacity locations with about four chargers each.

Utilization is key

Once an EV-charging station is built, all costs are essentially fixed, so utilization is key to achieving efficiency. Still, even a quite low utilization is likely to result in lines at busy times. In practice, the stand-alone, fast-charger industry uses a 20% utilization as a rule of thumb. But if a charging station is utilized at more than this 20% threshold, the operator will likely look to expand capacity or, more likely, add another site nearby.

Overall cost-to-serve

Although fast chargers are significantly more costly to build, their greater capacity means that their overall cost-to-serve (per KWH delivered) are competitive with lower-capacity chargers even at lower utilizations.

The “on-the-go” use-case

Third-party charging stations are significantly more costly than much slower-charging at home or at work. Nearly all EV owners, therefore, will probably use home and/or work chargers whenever possible, leaving a relatively modest proportion of the market for roadside locations. In fact, the cost disparity is so large that we believe the on-the-go use case will develop as an almost entirely distinct market—a bit like considering the option of a restaurant meal rather than eating at home. Roadside stations will likely then compete among themselves for the on-the-go market with little consideration of the at-home market (and its lower charge-up prices).

How will the “on the go” market develop?

Most EV owners are expected to do up to 80% to 90% of their charging overnight at home or during the day at work, estimates the US Department of Energy. In these use cases, Level 2 chargers will likely be used given that longer charging times don’t matter. Some EV-charging providers have experimented with Level 2 chargers at local destinations such as supermarkets, shopping malls and movie theaters, but these charge points may not capture loyal users. EV owners making short trips locally will rarely need to top up and, even if they did, slower Level 2 charging wouldn’t be of much help for anyone in a hurry. In contrast, “out-of-towners” on longer trips would need to charge—and would likely be willing to pay more for fast-charging (Level 3 or 4) to save time. One exception might be at hotels, where guests could charge their cars overnight. For out-of-towners, then, charging becomes a destination in itself, and these consumers would likely seek a combination of convenience, speed and competitive pricing—much as current consumers in today’s gas/diesel market.

It might follow, then, that locations for EV stations will mirror those of today’s gas stations—that is, quick and easy to find. But, with fast-charging so costly, this isn’t likely to be the case. The capital and capacity charges for Level 4 are approximately twice that of Level 3. In fact, to achieve the same profitability, a Level 4 station would need to charge a premium at least 10 cents/KWH over the price of a competing Level 3 station. On a 50 KWH (about 100 miles) charge, a consumer would pay a premium of about $5 to save around 15 to 20 minutes. This trade-off suggests that, over time, the market will segment with different providers targeting different consumer needs and preferences—much as occurs in the gas/diesel market today.

In the long run, we expect the EV-charging market to settle into four segments (as has the retail gasoline market): convenience-driven, price-driven, loyalty program driven and quality driven.

The four EV-charging consumer segments

Traditional gasoline segment	Approximate share of market	“Pure tone” behavior	EV analogous segment	“Pure tone” behavior
Convenience	55%	Turn in to next station when fuel light comes on	Time starved	Find nearest and fastest charger Will pay for time saved
Price	25%	Seek out lowest price station	Price	Will sacrifice time for lower cost
Loyalty program	10%	Earn and redeem points on gas	Loyalty	Earn and redeem points on a charge with partner retailers
Quality	10%	Seek high quality fuel/additives Strong preference for specific brands	Green power	Pay extra/sacrifice time for “green electrons”

In the emerging EV charging market, time-starved consumers will likely value their time highly enough to pay a premium for speed. They’ll look for convenient locations with the fastest charging times, and they’ll be disinclined to use reservations apps. Providers targeting these consumers will build extra capacity to maximize availability and offer the fastest chargers. They’ll also demand a significant premium over Level 3 stations seeking to capture value over and above the increased costs they incur.

The price segment consumer will likely go to Level 3 stations with higher utilization and, perhaps, in less convenient locations. Price-sensitive consumers may be willing to wait in line, shop around and reserve a charger via mobile apps. Out-of-town consumers would likely use chargers near aggregations of restaurants (or retail or amusement destinations) where they could occupy themselves while their car is charging.

In recent years, loyalty programs have become a critical competitive lever in the gas/diesel market. The loyalty segment in charging may not develop to the same extent since a household's total expenditure on away-from-home charging will be quite modest, representing only 10% to 20% of their total consumption. A vehicle averaging 10,000 miles per year, away-from-home charging will likely amount to roughly $300 per year, compared to at least $1,500 spent at the gas pump today.3

Nevertheless, we may see the emergence of bundles and other offerings, where service providers and retailers may offer charging as an incentive to drive subscriptions, traffic or other transactions and interactions.

A "quality" consumer segment may also emerge. This consumer prioritizes trusted brands they perceive as high-quality (in the same way some trust certain brands of gasoline). Differentiating the EV charging product itself (i.e., electrons) could be challenging, so providers may seek to differentiate and even brand the source of their power. For example, providers may promote green power from renewable sources such as solar, wind or geothermal—and charge a premium for it. Further, charging companies could brand power provenances. Imagine, for example, Texas Wind or Arizona Solar. Or, for some consumers, even Wyoming Coal?

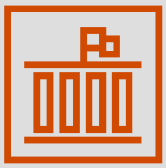
Who are the stakeholders of EV infrastructure?

Standalone EV charging providers

These companies are playing the long game. They're building charging capacity in advance of demand, absorbing losses and counting on the eventual rise in EV adoption. These players often seek to play in numerous EV-charging use cases such as installing home chargers (not unlike installing a home appliance) and at-work charging networks, setting up commercial locations (such as in parking lots of hotels or retail centers) and building roadside, fast-charging stations.

Vehicle OEMs (including consortia)

Vehicle OEMs are investing in charging networks across the US to drive demand for their vehicles. Some may offer charging for free (at least for some limited period) as an incentive to buy the car. These players typically negotiate deals with other businesses—a gas station or restaurant, for example—that pay fees in exchange for the prospect that the charger will draw customers. It seems to work. One convenience-store retailer that installed an OEM's chargers reported an 80% conversion of charges to store visits, with those store visits resulting in roughly twice the value of purchases compared to regular fuel customers.



State and local governments

EV adoption feeds into numerous state and municipal government environmental and sustainability goals. Some are either investing directly or subsidizing EV charging infrastructure development within their jurisdictions. Typically, though, these charging networks are Level 2 roadside/parking lot solutions which, as we've discussed, are a challenging use case. The upside, of course, is that these slow chargers are less costly to install.

Market sizing

As pointed out, most of the third-party charging capacity will likely be Level 3 and Level 4. The market size will then depend on EV penetration into the vehicle fleet parc, (i.e., vehicles in operation, as distinct from new car registrations) and the prevalence of on-the-go charging.

The table below illustrates the potential EV charger market size based on a mix of Level 3 and Level 4 chargers at different utilization levels.

Number of charge points required (in thousands)

	EV Penetration (% of total vehicle parc)				
Average charger utilization	**0.5%**	**1.0%**	**2.0%**	**5.0%**	**10.0%**
5%	47	94	188	471	942
10%	24	47	94	235	471
20%	12	24	47	118	235
30%	8	16	31	78	157

Source: PwC analysis

The current fast-charger network (47,000 chargers at a 5% utilization and a 0.5% fleet penetration) has been built ahead of demand and remains poorly utilized. We expect, however, that utilization will grow as the market and investor expectations mature. But utilization may well lag profitable levels for some time, as providers build out their networks in expectation of steadily increasing demand.

Given a central estimate of 5% penetration of EV total vehicle parc by 2030, the market could require about 120,000 to 235,000 fast-charge points or about 30,000 to 60,000 charging locations. Interestingly, smaller locations will probably drive adoption since they'll be more numerous and hence more convenient for consumers. Taking these considerations into account, we estimate the total fast-charging network in 2030 to be close to 60,000 locations with at least some of these—perhaps most—expected to be at existing gas stations.

While EV-charging remains in its nascency, we believe that the build-out of a national network of chargers that satisfies customer demand and preferences will do much to support greater adoption of EVs. Exactly how quickly this charging infrastructure will be developed—and precisely what it will look like—is not altogether certain.

Still, the underlying economics and analogous consumer behaviors should result in a network of convenient fast-charging stations competing to provide consumers with the electrons they need at competitive prices.

Note 3: The lower cost here is not due to lower cost per mile of an EV overall, but rather due to the fact that 80% of charging is done at home. In fact, the cost per mile for away-from-home charging for an EV is likely similar to or higher than a gas/diesel car today. In the gas/diesel market, consumers have no "at home" option, so the aggregate away-from-home spend is much higher.

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