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The evolution of the electric vehicle market

White Paper

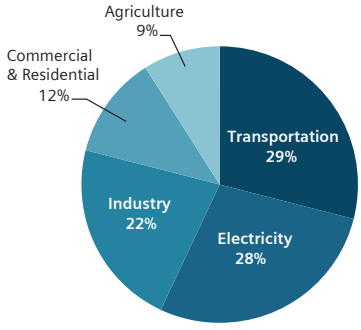
Pictured here is one of the first electric cars, an 1834 Baker[1].

A short history of electric vehicles

Few Americans realize the market competition between electric vehicles (EVs) and the internal combustion engine (ICE) began in the early 1800s. The first EV was developed in 1828 by Robert Anderson, but EVs didn't become commercially practical until the 1870. Pictured left is of an early EV. Not much different from a carriage, the early EVs had the same advantages EVs have today, "they [were] quiet, easy to drive and didn't emit smelly pollutants."[2]

EVs were one-third of all cars on American roads in the early 1900s but, the disadvantages of heavy, lead-acid batteries with limited range needing constant recharging prevented EVs from gaining more market share. In 1912 Henry Ford began to mass produce the Model-T and EVs couldn't compete with the low-cost vehicle. By 1920, the number of EVs on the road began to decline and by 1935 the EV all but disappeared from American roads. Fast forward to the 1960s and 1970s, when gasoline prices skyrocket, America began to rediscover EVs. In 1974, GM developed the modern, urban EV and by 1975 Sebring-Vanguard became the sixth largest US automaker with its wedge-shaped Citicar that had a range of driving 50-60 miles on one electric charge. Again, limited range and performance caused interest in EVs to wane, but the lack of emissions and greenhouse gases (GHGs) would cause a market resurgence in the early 1990s.

Total U.S. Greenhouse Gas Emissions by Economic Sector in 2017



Environmental concerns and efficiency

Climate change legislation limiting GHGs and studies around global warming in the early 1990s once again drew interest to EVs. Studies showed the largest portion of GHGs came from ICEs. In response to the environmental concerns of GHGs, automakers began to modify popular vehicle models.

Sources of greenhouse gases[3]

The adoption of EVs was an avenue to make a dramatic difference in global warming and climate change. Hybrids became a compromise between range and GHG reduction.

In 2000, Toyota introduced the Prius, an electric/gas hybrid that became an instant success. Tesla came on the market in 2006 with a plug-in luxury sport EV that had a range of 200 plus miles. The race for the EV market was on.

Between 2009 and 2013, the US Department of Energy invested in 18,000 residential, commercial, and public chargers. The last piece of the EV puzzle holding the EV market back was cost, more specifically, battery price. In the four years leading up to 2013, the price of batteries dropped by 50%[4] allowing the technology to compete with traditional ICE vehicle prices. Favorable adjustments in energy rates to charge EVs also continued to contribute to the attractiveness of EVs, as annual fuel savings are estimated at $440 to $1,070 [13] depending on the electricity provider.

Factors affecting EV adoption

- Today, there are over One million EVs on the road in the US. As of 2018, over 3 million EVs worldwide were on the road.[14] The number of EVs is increasing. Climate conscious consumers are responding to more competitively priced electric vehicles due to government rebates, lower up-front and maintenance costs, batteries with extended range, and more stringent state and federal emissions regulations, but there is still the need for charging infrastructure.
- Battery life/performance.
- Cost of installing a charger.
- Payment methods when charging on the go.
- Environmental impact on disposed batteries.

Market challenges

There are four major market challenges: vehicle cost, social change, battery technology, and infrastructure.

Vehicle cost. While EVs are less expensive to own due to lower maintenance and operating costs, they are more expensive up front. In 2018 a Nissan Leaf retailed for $29,990 while a Toyota Camry cost $23,645.[5]

To alleviate some of the cost disparity and encourage EV sales, the federal government is offering tax credits, which unfortunately continue to be at risk of being phased out. However, improved battery technology and lower battery costs continue to encourage the adoption of EVs. In 2018, the EV market share was 1.2%; it is predicted that by 2026, EVs will make up 7.6% of the total market.[6]

Social change. EV charge time and the ability to find a charger are market hurdles, because Americans are used to filling up their tank in two to three minutes and driving over 400 miles on one fill up. EVs charge in hours not minutes, and while 80% of vehicle owners charge at home during the night when electric costs are lowest, most EV owners experience range anxiety over their ability to find the next charge. Consequently, several SmartPhone applications have been developed which help consumers find the closest available charger, as well as track state-of-charge. Tesla is making inroads on battery charge time; their supercharger will recharge a car to 50% of charge in 20 minutes, but they are designed only for Tesla vehicles[12]—a drawback to deployment and for the consumer who owns a non-Tesla EV. The real opportunities here for both consumers and service providers are Open Standards like the society of automotive engineers (SAE) J1772 standard to ensure uniformity across EV charging ports and the connectors on the charger which plugs into the vehicle. Siemens has focused all its hardware on Open Standards like J1772, and the Siemens line of chargers include Open ChargePoint Protocol (OCPP) as part of the functionality to enable authentication and billing. This allows customers the freedom to charge with any other OCPP compliant charger and allows service providers the ability to easily change providers.

Battery technology. As recently as 2015, the battery made up 57% of the EV cost; today it is 33% and by 2025 it is projected to be 20%.[7] Improved battery life will reduce consumer concerns over replacement cost. Currently, Nissan, Chevrolet, and Tesla offer an 8-year/100,000-mile warranty and some have extended warranties up to 10 years.

Currently, Tesla batteries are expected to go 500,000 miles before a serious issue occurs. However, Tesla recently applied for a patent on a battery that will go one million miles.[15] The long life will have major importance for energy storage applications.[8]

Energy density is another consideration because consumers need batteries that not only charge quickly, but also travel long distances. "More energy density means less expensive vehicles with cheaper, lighter batteries that last longer on a single charge."[9]

Infrastructure. As state, federal and city regulations, along with climate consciousness, spur the purchase of EVs, there is a greater need for charging infrastructure. Table 1 details EV infrastructure.[16] To encourage the deployment of more charging infrastructure, utilities, energy providers, and city, state, and the

Cost ranges for charging infrastructure components

Cost Element	Lowest Cost	Highest Cost
Level 2 residential charger	$380 (2.9 kW)	$689 (7.7 kW)
Level 2 commercial charger	$2,500 (7.7 kW)	$4,900 (16.8 kW); outlier: $7,210 (14.4 kW)
DCFC (50kW)	$20,000	$35,800
DCFC (150 kW)	$75,600	$100,000
DCFC (350 kW)	$128,000	$150,000
Transformer (150-300 kVA)	$35,000	$53,000
Transformer (500-750 kVA)	$44,000	$69,600
Transformer (1,000+ kVA)	$66,000	$173,000
Data contracts	$84/year/charger	$240/year/charger
Network contracts	$200/year/charger	$250/year/charger
Credit card reader	$325	$1,000
Cable cost	$1,500	$3,500

Table 1

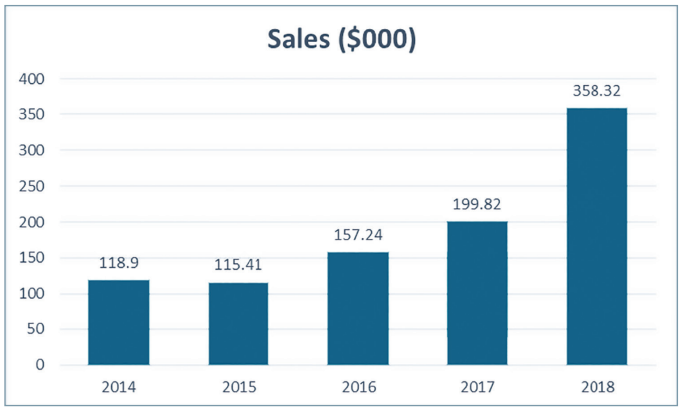
Note: DCFC denotes direct-current fast chargers.

federal governments have instituted tax credits and rebates. Additionally, charging stations can be an income producing asset, which is also an incentive for commercial businesses. EV service providers have sprung up and promise help with installation and management of the charging infrastructure, which in many cases has made it an easy choice for businesses, workplaces, multi-family homes, etc. to provide the benefit of charging EVs to their employees and tenants. The biggest drawback some of these new providers of charging have had to face is the contract for maintenance and operation of these connected charging stations that have been deployed at their property. If for any reason the site owner is unhappy with a proprietary network, they cannot easily change their supplier.

Market innovations

Fortunately, there are many innovative companies with a wide variety of solutions to address service provider concerns. But, how do you choose the right solution provider that will supply you with the right expertise and technology, while creating an income stream for the owner/operator? Some hardware producers that supply both residential and commercial hardware solutions have added software solutions for communications such as smartphone applications and open access protocols with billing management software listed in Table 2. Mobile applications, Wi-Fi, RFID chips, credit card readers, and OCPP embedded chargers make payment easier at public charging stations. Asset management software allows station owners to track assets, costs, and income.

The improved US charging infrastructure does make charging easier (see Department of Energy chart above), but there is a problem: some major EV network service providers utilize proprietary communications from the charger, and that locks a charger owner into that charger's cloud service. This means the owner of the charger can never go to another network provider



The number of public electric vehicle stations and charging outlets in the US as of December 2018.[10]

for service without also purchasing new charging hardware. Luckily, this problem is easily solved by using the EV industry's standard communications protocol, OCPP. "OCPP is simply a syntax (language) used to communicate between a networked charging station and a network management system,"[11] or Siemens cloud service backend. As infrastructure is built, service providers found that neither they, nor their customers, want to be locked into one network provider—customers want the convenience of doing business with any network provider and move their charging assets to different network providers whenever they choose. With OCPP built into the charger, they can change service providers whenever they are unhappy, or if it makes economic sense. The service provider's customers do not want the inconvenience of belonging to numerous networks with memberships in each one and numerous RFID dongles to access that network. OCPP makes paying for the charge much easier. Service providers can change networks anytime they are not happy with a provider and their customers can charge at any

Manufacturer	Level 1 (Free AC Charger W/ Car)	Level 2	Level 3 (DC Fast Charger)	Mobile App	EVSE Asset Mgmt.	Wi-Fi Enabled	OCPP Built into Charger	Credit Card Reader	RFID
ABB		X	X	X	X	X	X	*	X
Blink**		X	X	X	X	X			X
ChargePoint***		X	X	X	X	X			X
Clipper Creek		X	X	****		X	±		
eMotorwerks – Enel X				X	X	X			X
EVGo		X	X	X	X	X			X
Greenlots				X	X				X•
Juice Box		X	X	X	X	X			
SemaConnect		X		X	X	X	X		X
Siemens	X	X	X	X	X	X	X	X	X
Tesla	X	X	X	X	X	X			X

Table 2

*ABB offers a credit card payment module through their app, not a credit card reader.

**Blink's business model is one of equipment leasing to commercial businesses only.

***Charging Stations require subscription to SaaS Offerings. The Charging Station are designed to work with ChargePoint's cloud-based application services ("SaaS Offerings"). Access to SaaS Offerings requires the Purchaser to enter into a Master Services and Subscription Agreement with ChargePoint (the "Cloud Services Terms").[9]

****Clipper Creek mobile app can be downloaded to a smartphone but can ONLY be used to find charging locations.

±May require Liberty plug-in subscription.

•Members can order RFID cards online for a $9 fee.

OCPP enabled charger. To avoid any interoperability/scalability issues, vendors should guarantee the hardware is OCPP compliant and will work with at least two other OCPP compliant charging station providers and data handling backends.

The adoption of the OCPP protocol is global. However, some with proprietary networks have not yet adopted this standard. Currently, only Siemens offers the complete spectrum of innovations from OCPP, Wi-Fi, smartphone application for easy payment, asset management software, and credit card readers. With a focus in technology, Siemens eMobility® provides an array of charger products specifically designed to meet each customer's needs and the market's challenges.

Siemens is committed to eMobility, today and in the future. Siemens PlugtoGrid™ offering is a portfolio encompassing solutions like, hardware, software, and services that can meet the electrification needs of any charging infrastructure. Because of this commitment, customers will have a partner with experience from the initial needs survey, to equipment selection, installation, to hardware and full asset management. PlugtoGrid allows utilities, transit authorities, and multi-family dwellings, buildings, and parking lot owners the flexibility to design and develop a reliable infrastructure that will be supported for years to come.

Published by
Siemens 2020

Siemens Industry, Inc.
5400 Triangle Parkway
Norcross, GA 30092

Siemens Technical Support: 1-800-333-7421
info.us@siemens.com

Order No. SIDS-M40030-00-4AUS

Printed in USA

usa.siemens.com/eMobility

Footnotes

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