EV market and wireless charging

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Introduction

Electric vehicles (EVs) will be just one of many changes in the rapidly emerging and vastly different transportation industry. Autonomous vehicles, along with more ride sharing and vehicle sharing (much like today's bicycle-sharing services) are also all on the horizon. Infrastructure changes such as plentiful charging options, including wireless charging, aren't far behind.

The already significant momentum behind EVs is building. More consumers are buying EVs, and governments across the globe, car manufacturers and technology providers are working on necessary advancements like cost-effective batteries.

EVs crossed the 1 million mark in 2015 and doubled a year later[1]. Based on this kind of growth, forecasters expect that by 2020, 9 to 20 million EVs could be on the roads, with as many as 40–70 million by 2025. As of 2016, 14 countries[2] had established aggressive targets for the rapid deployment of EVs, with plans to phase out vehicles powered by internal combustion engines (ICE). This list includes China, Germany, France, the United Kingdom, South Korea and eight states in the U.S. Several countries set a date for eliminating ICE vehicles entirely—see Table 1.

Country	Goal for transition to EV
United Kingdom	Banning ICEs by 2040
France	End sales of ICEs by 2040
India	EVs only for sale by 2030
Norway	Only zero-emission vehicles by 2025

Table 1. *Government plans to transition to EV.*

Another factor spurring the adoption of EVs will be improved cost-competitiveness with ICE vehicles. Improving battery technology has a lot to do with this, since the battery is typically the costliest aspect of an EV. From 2010[3]–2016, the cost per kilowatt hour (kWh) of battery capacity dropped from around $1,000/kWh to slightly more than $200/kWh. Consulting company McKinsey & Co. expects this figure to continue to drop until EVs achieve cost parity with ICEs—which the International Energy Agency expects will happen by 2030[4].

Of course, automotive manufacturers are watching all of these trends, as well as Tesla's phenomenal early success. For example, Volkswagen recently announced a major shift toward electric powertrains. The company said it would have 30 electric models by 2025, a year in which it plans to sell between 2 and 3 million EVs. Other manufacturers, like GM's Chevrolet, Daimler AG, Ford Motor Co., Honda, Renault, Nissan and Geely's Volvo have announced similarly aggressive EV sales expectations.

With all of these dynamics at work, it will be interesting to see how the adoption of EVs plays out over the near, medium and long term.

Near term: The early EV adopters

Typically, the early adopters of new technologies are willing to look beyond any perceived limitations or inconveniences; they see the eventual potential of the product or device. Early EV adopters have been willing to accept a higher purchase price relative to ICEs, for example. Plus, they can endure "range anxiety" caused by the EV's limited range per battery charge. Indeed, many early EV adopters realize that their driving habits seldom exceed the range of an EV and that they can recharge the battery when they're not driving the vehicle.

Moreover, early EV adopters have not been overly concerned about the lagging infrastructure of installed electric vehicle supply equipment (EVSE). Publicly available charging stations are relatively scarce, and an EV's time-to-full-charge takes longer than gassing up an ICE. Still, an analysis of typical driving patterns reveals that a high percentage of EVs do sit idle and are available for charging for long periods. EVs do have a certain advantage over ICE vehicles because EV drivers who charge their vehicles where they are parked do not have to go out of their way.

Besides adding more charging stations, the power grid itself will need some work to efficiently manage the new demands that charging EVs represents. For example, turning on too many ultra-fast charging stations deployed in a concentrated area simultaneously could cause spikes and possibly even service disruptions on the grid. So while fast EV charging makes sense on highway corridors and interstates, slower, steadier, "trickle" charging during vehicle downtime when parked may ultimately make the most sense for the grid.

Even with these limitations, early EV adopters are still quite willing to be among the first to own and drive an EV.

Medium term: The roaring 2020s

As the EV market continues to grow in the not-too-distant future (around 2020), many of today's inconveniences and shortcomings will start disappearing. Because of this—and because of the approaching cost parity of EVs and ICE vehicles—the mass adoption of EVs will be in full swing.

Battery technologies will continue their development curve, increasing power densities, decreasing charging times and simplifying the charging process, with more convenient access methods. The driving range for EVs will inevitably rise to 300 miles or more, comparable with a tank of gas for an ICE vehicle. In fact, the International Energy Agency expects EV mileage ranges to triple during the 2020s[5].

In addition, a more robust and diverse charging infrastructure for all sorts of EVs will take shape throughout the 2020s. Countries are already planning networks of strategically located fast-charging facilities to support road-trip driving. Slower trickle-charging outlets will find their way into residential garages, as well as businesses and commercial charging facilities in urban areas. For example, China has a target of 4.3 million private and 500,000 public charging outlets by 2020. France hopes to have 7 million charging outlets by 2030[6].

Strategic planning will be critical during the buildout stage of the charging infrastructure to ensure the proper balance between fast and trickle charging, as well as public and private charging facilities, so as to effectively manage the effects of EV charging on the distribution grid and power-generation plants.

New charging technologies and methodologies, such as automatic wireless charging located in residential garages, airport taxi queues, and retail and office parking lots, can help mitigate possible power spikes or service disruptions on the grid while

Figure 1: *Public Infrastructure.*

still keeping EVs "topped off." Charging stations will also become smarter, capable of what is known as bidirectional charging. The vehicle, charging equipment and grid will communicate and share information, ultimately returning back power to the grid as needed in exchange for EV owner incentives.

Some EV drivers, such as those who only commute to work, will only need to charge their batteries at home overnight. For many drivers, their daily miles will be decidedly less than their EV's mileage range and they may have power to spare.

While parked with an always-on wireless charging connection, bidirectional charging could let EV drivers make arrangements with their power providers whereby they might, for example, offer a few kilowatts of power back into the grid when demand is high in exchange for free or reduced cost power at a time when the grid has excess, underutilized capacity. Because utilities are much more efficient when their demand curve is relatively smooth rather than marked by peaks and valleys, they may be more willing to provide power at a reduced rate during times when demand is lower in exchange for not having to provide as much power when demand is high. Multiplied by a large number of EVs, the resulting reduced demand for electrical power generation, combined with on-demand supply by participating EVs, would likely be huge.

The expanding EV support infrastructure will include a diverse set of charging options, including both wired and wireless connections to the power grid.

Since the speed and efficiency of both wired and wireless charging are virtually identical, convenience will be an important consideration for EV owners. In fact, no charging method is 100% efficient; both wireless or wired charger efficiency can range from a low of 80% to a high of 96%. And whether a charging station is wireless or wired has no bearing on the speed of the charging process.

An autonomous future

The pieces of the puzzle that will eventually become a smarter and more autonomous transportation system are already taking shape. Of course, high-profile companies such as Google, Uber, Tesla and BMW have made much progress on autonomous vehicles, but to propel these new solutions into reality, it's just as important to be innovative in developing the infrastructure.

The rise of autonomous vehicles will ascend simultaneously with EVs. One industry research firm forecasted[7] 85 million autonomous vehicles on the road by 2035. Of course, it doesn't make much sense to develop a vehicle that can go without a driver but still requires manual plugging into a charging station. Thus, new automated wireless charging processes will also emerge. For example, a fleet of autonomous taxis could drive themselves to in-service stationary wireless charging facilities, parking and recharging wirelessly with no manual intervention.

Some locales will support dynamic charging in addition to the traditional stationary charging method. Dynamic wireless charging occurs while the vehicle moves over wireless charging equipment embedded in the road. Eventually, grids of dynamic charging roadways will be built in high-traffic areas such as city centers, airports or bus routes. Dynamic charging could reduce battery sizes, bringing down vehicle costs and encouraging even wider adoption.

Figure 2: *Shared fleets with EV wireless charging.*

Of course, innovative technical solutions will enable new and creative business models, which will in turn accelerate the proliferation of the overall technology. Ride-sharing services like Uber and Lyft have become an integral part of the transportation system. The transportation system of the future, with its reliance on EVs and autonomous cars, will feature car sharing and other services that could make owning a car less of a necessity. For example, commuters might subscribe to an autonomous car sharing service that could dispatch vehicles as they were needed, or a driverless vehicle might routinely pick up commuters every day and take them to work. Instead of owning two or more vehicles, a household could get by with one or none.

WiTricity wireless charging

As autonomous EVs evolve into a primary mode of travel, wireless charging will become an essential element in the transportation system of the future. The application might be a park-and-charge system or dynamic charge-on-the-go, but wireless charging will be the base technology. It eliminates the need for human intervention in the charging process, and provides a safe and efficient way to energize autonomous EVs for maximum utilization.

WiTricity develops wireless charging solutions for EVs using its patented magnetic resonance technology to enable a hands-off charging process at equivalent charge times and efficiencies as wired charging stations. The wireless charging infrastructure and vehicle components are being developed now and will be in deployment as EV usage grows and autonomous EVs become common. North American and international standards are emerging that will ensure vehicles can seamlessly charge at any wireless charging station. WiTricity works with top global carmakers and Tier 1 parts suppliers to deliver the magnetic resonance solutions that will help realize a future of transportation that is electrified, shared and autonomous.

Figure 3: *Home EV wireless charging system.*

The DRIVE reference design meets the needs of vehicles ranging from PHEVs with small capacity battery packs to EVs with high-capacity, long-range battery packs. DRIVE has the ability to charge vehicles from 3.6–11 kW (future 22 kW), ranging from low-ground-clearance sports cars to medium-ground-clearance sedans to high-ground-clearance SUVs, all with a single system design. Designed for the utmost in interoperability, the DRIVE ground assembly (GA) is capable of on-ground and in-ground, flush installation. The combination of high efficiency, low emissions, cost-effective architecture and interoperability make it the leading wireless charging reference design globally.

Enabling real-time power conversion

The real-time power conversion that is at the heart of wireless charging systems is demanding—both in terms of the processing power that the system needs to run but also with the resources that processing elements must have at their disposal. Texas Instruments (TI) 32-bit C2000™ real-time microcontrollers (MCUs) have already demonstrated their prowess in EVs and EVSE infrastructure systems.

C2000 MCUs feature a powerful digital signal processor (DSP) capable of the high-end mathematical calculations essential in real-time-control power electronic applications. The C2000 MCU family includes a number of advanced on-chip analog-to-digital converters (ADCs) as well as high-resolution pulse width modulators (PWMs). A full selection of peripheral interfaces and communication options make the C2000 MCU a good fit for smart EV wireless charging platforms.

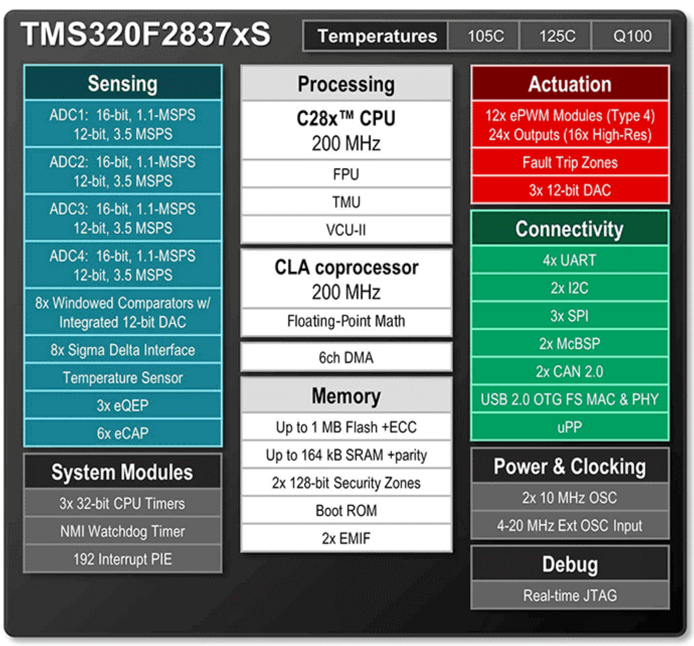

***Figure 4:** C2000™ microcontroller block diagram.*

Conclusion

A smarter, autonomous, safer, cleaner and more effective transportation system is taking shape. We're in the early stages now, with an increasing number of EVs on the road and many more introduced EVs every model year. The foundational technologies of much of the new transportation infrastructure—wireless charging systems, better batteries and powerful processors to manage all of the complexities—are already here. Tomorrow can't be far behind.

Resources

1. *Global EV Outlook 2017*, by the IEA, page 6
2. *Global EV Outlook 2017*, by the IEA, page 23
3. Source: *Business Insider*, 10/9/2017
4. *Global EV Outlook 2017*, by the IEA, page 21
5. *Global EV Outlook 2017*, by the IEA, page 23
6. *Global EV Outlook 2017,* by the IEA
7. Navigant research as referenced in the article "Wireless Charging and autonomous vehicles will mobilize the smart city" by Alex Gruzen in *Charged* magazine.

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