MARKET INSIGHTS

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Speed Bumps in the Road: Analyzing Key Challenges to Electric Vehicle Adoption

A Technical Supplement

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The structural threat to the energy sector hinges on the continued advancement of electric vehicle (EV) technology and adoption. This supplemental article addresses some of the potential technical challenges for EV adoption which we encountered while researching EVs. As always, when looking at a structural change there is considerable uncertainty about timing and technologies. This supplement is intended for those that may have similar questions about the evolution of EVs or are simply interested in learning more.

Can the Grid Sustain Mass EV Recharging?

Forecasting the future electricity demand from electric vehicles is difficult because there are many unknowns, including the EV adoption curve, availability of incentives, infrastructure build-out, the price of gasoline and the general health of economies. If all drivers of light-duty vehicles switched from gas to electric vehicles, would electric grids have the capacity to recharge all EVs today? If the switchover was a dramatic one-day event, the answer would likely be 'no'. Luckily, Rome was not built in a day.

If all light-duty vehicles in the US were replaced with EVs, they would require about 1,000 Terawatt hours (TWh) of additional electricity per year, or an increase of about one-quarter of our current electricity demand.[1] One TWh is equivalent to the power required to electrify 100,000 homes in the US.[2] An extra 1,000 TWh of demand would be more than enough to overload existing systems.

However, with sufficient demand-side planning and active load management, and a gradual switchover to EVs, material EV adoption can be supported by the grid and may even prove to be supportive of overall grid stability.

Electricity demand attributed to new EVs can be managed with proper planning by utilities such as time-of-use (TOU) pricing that may become common practice by 2020. Utility companies have made significant development in managing peak energy demand with the deployment of smart meters. TOU pricing alters consumer behaviour by reducing electricity prices in off-peak times to limit the demands during peak periods. For example, with electricity half the cost between 7pm and 7am versus full costs between 7am to 7pm, consumers are nudged to run their dishwashers and washing machines in the evening versus during the day. By extension, there would be incentive to recharge their EVs overnight versus during the day. Imagine how many people would fuel up their gas-powered cars if gas was half the price after midnight.

It is important to realize that electricity demand varies substantially over a day, and the grid has been built with significant excess capacity in order to be able to meet peak periods of demand. Utilities, such as PG&E in California, have already begun to experiment with using EV demand to smooth out daily peaks. PG&E pays EV owners for the right to control when vehicles are charged, allowing the utility to use EV charging as a buffer for the grid.

[1] IEEE webinar with Mike Jacobs and Peter O'Connor of Union of Concerned Scientists, "Questions and Answers on Storage and Vehicle Charging as Renewables Arrive," February 4, 2016. http://smartgrid.ieee.org/resources/ webinars/past-webinars?eid=61&m=d7ad069d3940ebcaa f9ce65812521293
[2] E-mobility: Closing the Emissions Gap, World Energy Perspectives, 2016.

Demand could be further mitigated at the local level with emerging technologies such as vehicle-to-grid (V2G) solutions. The concept behind V2G is that, when vehicles are not in use and plugged into the grid, EVs help buffer peak energy demand by supplying the grid with energy at the margins. These programs can help mitigate peak load levelling and also lay the foundation to act as a buffer to less stable renewable energy generation such as wind and solar.

While the grid can currently allow for the charging of tens of millions of cars, and since a complete transition to EVs will not happen overnight, the electricity grid has plenty of capacity to support a material rollout of EVs. V2G and TOU implementations create the ability to provide greater efficiency to the electric grid.

What about the Availability of Charging Stations?

It's becoming clear that a robust charging network is required to spur greater demand for EV adoption. Research shows some of the top reasons for rejecting EVs are related to charging infrastructure or driving range.[3] Recent projections for global charging-station deployments estimate that public and private installations could grow from around two million in 2016 to over 12 million in 2020.[4] Governments and auto-makers around the world have announced commitments to investing in charging infrastructure over the next ten years.

While the intra-city infrastructure is being built, the current lack of inner-city infrastructure may not necessarily impede day-to-day requirements of electric vehicles. Given that most one-way commutes to work are less than 50 kilometers and late-model EVs have up to 360 kilometre ranges, inner-city charging stations should not really be a concern. The infrastructure challenge may be more about mindset than reality for day-to-day usage for more than half the population of drivers that live in a single-family detached home. Our society has a habituated reliance on gas stations to fuel internal combustion engine (ICE) vehicles. Therefore, switching to EVs may be more a function of breaking old habits for new. For example, plugging in the EV when at home at night instead of going to the gas station to fuel up. In this instance, consumers can be incentivized financially to change their habits, given that electricity is cheaper per mile than gasoline (approximately 1/10th the cost).

Unfortunately, less than half of US vehicles have an off-street parking space at an owner-occupied residence where charging infrastructure can be installed.[5] Installation of charging stations at apartments and other multi-dwelling units would be required to unlock greater adoption of EVs.

The cost of charging stations varies, depending on the location and the charging capabilities required. But costs do not appear prohibitive when contrasted against the fuel and maintenance savings[6]:

- Level 1 Home: No cost, assuming a standard 110-volt outlet is available in the garage
- Level 2 Home: US$650 - $2,000
- Level 2 Parking Garage: US$4,050 - $7,500
- Level 2 Curbside: $5,300 - US$13,100
- Level 3 DC Fast Charging: US$29,650 - $80,400

The difference between Level 2 and Level 3 is the difference between hooking up to a household plug (three-prong, oven-style), which requires eight hours for a full charge, and using a special outlet that can get batteries up to 80% charged in about 30 minutes.

Charger Levels Explained[7]

Type	Voltage (V)	Max Capacity (KW)	Time to Charge an EV with a 96 – 130 KM Range	KMs Added per Hour
Level 1	120	2	14-22 hours to full charge	4-8
Level 2	240	4	4-7 hours to full charge	20-32
Level 3	480	20 - 90	30 minutes to 80% charge at 20 kW	96-130 at 20 kW

3 Peterson, David, "1700 Fast Chargers by 2016," presentation to the California PEV Collaborative, Nissan North America, March 10, 2015, slide 6 citing survey by PG&E and RDA Group, 2014.
4 IHS Automotive
5 Traut, Elizabeth et al., "US Residential Charging Potential for Electric Vehicles," Transportation Research Part D 25 (November 2013): 139-145.
6 https://rmi.org/news/pulling-back-veil-ev-charging-station-costs/
7 Electric Vehicles as Distributed Energy Resources", Rocky Mountain Institute, June 2013

Are There Enough Battery Materials for the EV Transition?

Battery technology has come a long way and continues to make advancements as better, faster and cheaper materials and processes become new norms. Scale is becoming a massive factor in driving down costs, as we have seen with Tesla and the recent introduction of its Gigafactory, the largest building in the world by footprint (roughly 100 football fields). Gigafactory is expected to enable Tesla to reduce battery manufacturing costs by 30%. The price of batteries will be driven down further as conventional auto manufacturers roll out new EV models.

While there has been no shortage of key battery ingredients, it is important to consider whether raw materials are plentiful enough to support a full conversion to EVs. The primary materials used in a Tesla battery are lithium, graphite, nickel, aluminum and cobalt. Nickel and aluminum are widely available common elements but the other three components are less common.

Lithium – This mineral provides the highest energy density of common battery materials and has the ability to be recharged many times without loss of capacity. The good news is this mineral exists practically everywhere in the world. Currently, 75% of lithium is produced in Argentina, Chile and Bolivia. The price of lithium has skyrocketed from growing demand for laptops, smartphones and, more recently, a surge in EVs, which is now driving a supply response.

Graphite – Demand for graphite is expected to increase dramatically as this component is used as anode material in lithium-ion batteries. China accounted for 66% of graphite production in 2016; however, Canada also produces graphite. Tesla's interest in creating a North American supply chain may expand opportunities for Canadian producers. Unlike the other materials in a lithium-ion battery, graphite can be produced synthetically, with synthetic graphite already used in some lithium-ion batteries.

Cobalt – This is the key ingredient in creating high-powered lithium-ion batteries, and 55% of all cobalt production comes from the politically unstable Democratic Republic of Congo. Unlike the other battery materials, cobalt supply appears to be a potential bottleneck, with current global production sufficient to supply an estimated 15 million vehicles per year, with much of current production already being used for batteries for personal electronic devices. This is well below global automobile sales of around 75 million vehicles.

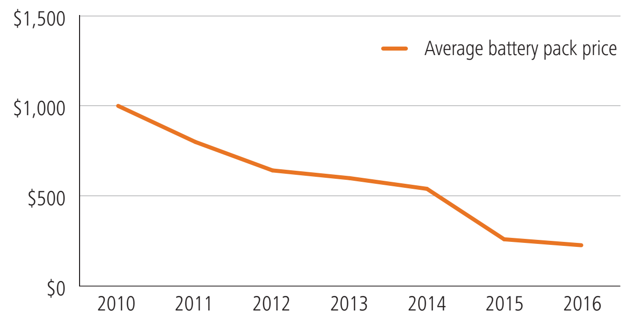
While, in the short-term, supply questions exist for lithium, graphite and, most pressingly, cobalt, it is important to keep in mind that battery chemistries are expected to evolve. There is considerable research globally to replace or reduce the amount of cobalt in a lithium-ion battery, without sacrificing performance. In addition, other chemistries are being utilized, including lithium-iron-phosphate, which is heavily used in China, the world's largest EV market.

Battery scientists continue to innovate, through new formulations and component materials, increasing the specific energy and power relative to current lithium-ion batteries. However, experts believe lithium-ion batteries will continue to increase capacity by 6-7% annually for a number of years from better engineering, improving energy density through cathode and anode development, and efficient manufacturing at greater scale.

Will Battery Costs be Affordable?

Consumers are excited about the prospect of owning an EV (30% of US consumers consider an EV purchase today)[8] but cost is a major deterrent. The battery is the biggest cost. What is interesting, however, is that costs have come down a long way in a short period of time (see chart below). From 2010 to 2016 battery prices fell almost 80%. In fact, the cost curve has beaten expectations as costs slide more quickly than anticipated.

Average Battery Pack Price (USD$ per kWh)[9]



[8] McKinsey&Company, "Electrifying insights: How automakers can drive electrified vehicle sales and profitability", January 2017
[9] McKinsey&Company, "Electrifying insights: How automakers can drive electrified vehicle sales and profitability", January 2017
[10] http://www.nyc.gov/html/tlc/downloads/pdf/2014_taxicab_fact_book.pdf

When battery costs reach US $100/kWh, mass-market EV costs are expected to reach parity with ICE vehicles, though overall ownership costs should be less than an ICE vehicle given cheaper fuel and maintenance costs. In addition, we can expect a quicker changeover in fleet vehicles such as taxis. When you consider that, on average, taxis travel 112,000 kilometers per year[10], the savings in maintenance and refueling costs, measured in cost per mile, means the economics may already make sense today as compared to personal-use vehicles for the break-even point.

Battery cost is also a major consideration for EV range. As battery prices decline, manufactures and consumers can choose between a lower price and a larger battery. This allows for the option of longer-range vehicles, if consumers require them.

EVs appear to be approaching the point of rapid and wide adoption, as they gradually become both cheaper and better than conventional internal combustion vehicles. Although there are potential bottlenecks, including adapting the grid, rolling out charge stations, and continuing to improve battery performance and chemistry, we do not see any significant weakness in the supply chain that will inevitably halt continued progress. As a result, we believe that the adoption of EVs will slip past the tipping point sometime between 2020 and 2030, which we believe will be a structural challenge for the energy sector.

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