Will Electric Vehicles Transform Distribution Networks? Only Time will Tell

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See footnotes at end of text.

Around the world, governments and societies are pursuing transformations to energy systems. Most of these involve "electrification": electrification of the vehicle tailpipe, i.e., displacing internal combustion engine (ICE) transport with partial or fully electrified versions. Pure battery electric vehicles (BEVs) would likely, perhaps overwhelmingly, rely upon local electric distribution company (disco) networks for recharging as would plug-in hybrid electric vehicles (PHEVs). All electrification scenarios bear implications for power generation (technology and fuel mix), transmission (for remote and intermittent generation) and distribution (for all of the end use applications). These efforts are being undertaken with beliefs that: net reductions in carbon can be achieved without sacrificing reliability and security of energy systems and economies; open, competitive market regimes are compatible and can be preserved; the scope of policies and mandates are complementary with consumers' willingness and ability to pay the consolidated costs. Are these assumptions accurate? Is there sufficient scrutiny to support beliefs? What are the missing links and considerations?

Zoom-Zoom

The energy transformation stakes are highest when it comes to views about the future of transportation and mobility, because these entail enormous shifts in technology, materials, supporting supply chains, consumer tastes and preferences, demographic and geographic context. It should be no surprise that pace and timing of electrification are expected to be quickest in urban corridors, the denser the better, tapping into discos that are often old and expensive to maintain and repair (much less to improve). Conventional wisdom has it that metropolitan markets around the world can accommodate increasing shares of various types of electric vehicles, all integrated into local distribution grids for charging and/or balancing energy flows, with interactive metering to convey signals between supply and demand. EVs generally fit into ambitions for distributed energy resource (DER) approaches that offset or supplement disco operations. Balancing these views are standalone, self-sufficiency concepts for remote energy capture – solar, for instance – with EV and other battery energy storage. Nirvana! But what really is going on in the auto world with EVs?

The range of possibilities and associated challenges means outlooks for EV growth and market share vary greatly in both methodology and results. Where some organizations project to 2025, others look much further to 2100 for detectable alterations. Where some consider policy or consumer preference as primary drivers, others attempt to account for both while adding other factors such as technology. All are moving targets, of course. It is not only the values across the different projections that differ. The range of possibilities provided within individual outlooks are broad as well, contingent upon scenarios. For instance, in its May 2018 *Global EV Outlook*, the International Energy Agency (IEA) projected global EV deployment ranging from 40 million to 70 million by 2025, while the U.S. Energy Information Administration (EIA) in its January 2019 *Annual Energy Outlook* has 8 to 26 percent of the global fleet electrified by 2040. Bloomberg New Energy Finance in their 2019 *Electric Vehicle Outlook* puts 559 million EVs on global roads by 2040, or 55 percent of new car sales. The span of possibilities constitutes a "5x" spread for 2030, a relatively close time target.[1] For proper perspective, these outlooks and projections compare to a U.S. private, light duty vehicle fleet of more than 275 million cars, with annual sales of new autos at about 17 million and used of about 40 million, and a worldwide auto fleet of about one billion.

Against these wildly varying aspirations and forecasts, the auto and electric power industries and their myriad suppliers and vendors must make hard decisions while at the same time operating their core businesses soundly if they are to survive and thrive with ability to invest in the murky future. And so forecasts from original equipment manufacturers (OEMs) are equally varied. Volvo announced that by the end of 2019, each of its vehicle models will be electrified. This comes in the form of fully electric vehicles, plug-in hybrids, and mild hybrid vehicles that do not require charging. Additionally, the company plans to release five new fully electric models by 2021 and aims to have over one million of their electric vehicles on the road by 2025. Similarly, BMW announced they will release five new fully electric options by the end of 2021. BMW's target increased to a total of 12 electric and 25 hybrid models by 2025. The company stated a goal of putting half a million electric vehicles on the road by the end of 2019. BMW can manufacture the engines for battery electric, plug-in hybrid, and internal combustion vehicles on the same production line, which helps the company to streamline manufacturing and increase efficiency during its transition to increased electric options. Along with shifting portfolios of vehicle models are corporate goals for their own operations. For example, Toyota turned its attention to the manufacturing process and set numerous sustainability goals for the company. Overall, the company aims to have a net-zero environmental impact through maximizing the efficiency of their water usage, ensuring recycling, and addressing vehicle-related emissions. Toyota's goals include zero carbon dioxide emissions from new factory plants as well as achieving a 90 percent reduction in carbon dioxide emissions from their vehicles by 2050 as compared to the 2010 values.

There are, of course, alternative designs that OEMs are developing, like hydrogen fuel cell vehicles (HFCVs) and ICE vehicles coupled with cleaner fuels of various types. Toyota's long-term goal of pursuing fuel cell vehicle options is one of the more aggressive, with active partnerships and investments in hydrogen fuel and infrastructure to support vehicle sales. Other OEMs have HFCV designs although most opinions are that it is likely to take longer for alternatives like HFCVs to penetrate the market in meaningful shares; for many OEMs HFCVs are geared toward the heavier duty vehicle markets where re-fueling can more easily be integrated into commercial fleets. OEMs also readily acknowledge that improvements, some quite deep, still can be made to ICE vehicles that may prolong competitiveness of conventional transportation and fuels. Transportation fuel suppliers and OEMs also are pursuing new fuels that may offer substantial environmental benefits. Coupled with the performance metrics already prized in the higher energy density petroleum-based combustion engine design, ICE vehicles may persist longer than many expect.

Building global aspirations and outlooks for possible and potential EV penetration is one thing. Auto makers cannot respond unless vendors and suppliers are able to rise to the occasion. OEM commitments for different models mean required changes in manufacturing. Manufacturing typically does not come into play directly in outlooks; clearly, the more aggressive an energy transformation/electrification view of the future, the more likely it is that underlying manufacturing constraints are assumed to be met. Yet fundamental, structural changes will be necessary to ramp up production if forecasted EV growth is to be met. Global OEM vendors and suppliers have increasingly taken note of ambitions for electrification and are beginning to make changes in their business models. These changes typically include investments in technology such as battery cooling systems and electric motors, as well as including electric drivetrain manufacturing.

We surveyed a number of OEM suppliers, finding strongly divergent responses. For instance, Continental AG has begun to further develop its powertrain division, which became an independent group in the beginning of 2019. In addition to ICE powertrains, the group also covers electric vehicle and hybrid parts. Because of the increased costs associated with this transition, the corporation noted a decrease in earnings expectation in the short term (considerations for earnings as companies weigh strategic responses is a common theme, including for OEMs and fuels suppliers). Despite this, Continental AG's powertrain division has continued its investments, developing a plant in China, a common destination.

Like Continental AG, Bosch formed a new powertrain solutions division in 2018, which focuses on three market segments: passenger ICEs, commercial and off-highway transportation, and electric vehicles. In addition to electric powertrains, Bosch is also developing an e-axle for heavy trucks with fuel cell powertrains. The company understands the importance of electrification for stated policy goals and greenhouse gas emission targets; however, Bosch expects a slow transition to fully electric vehicles, as even new combustion engine powertrain technology can help in emissions reductions. Given that perspective, Bosch is continuing to develop a variety of components for ICE, hybrid, and fully electric vehicles.

Increasing its options of electrifications products, Denso offers car drive systems, power supply, starting system parts, and small motor systems for hybrid and electric vehicles. Additionally, the company is working to enhance the efficiency of ICE vehicles in developing countries, where the key to promoting environmentally-friendly vehicles in these countries is by optimizing and reducing the cost of the existing technology. The company reported an eight percent increase in revenue from electrification systems, citing increased sales of electric products for hybrid vehicles in Japan and China. Denso has recently developed a new flow valve for improved fuel economy through temperature management in battery hybrid and electric vehicles.

In spite of a temporary shut-down at a location in Ohio, Hyundai Mobis sales increased in 2018 in part due to increased production volume of BEVs. Hyundai Mobis reported a year-over-year increase from 2017 to 2018 in part related to electrification.

Shifts in the transportation industry are leading to new partnerships between companies and across industries. For example, Bosch collaborated with Nikola Motor Company to develop an electric powertrain and "eAxles". The company also partnered with NIO, an electric vehicle manufacturer, for advanced sensors, automated driving technology, and electric motor management. Similarly, Denso is working with Toyota to further electric vehicle technology. Magna International has entered into a joint venture with Beijing Electric Vehicle Company to build an EV production facility in China, with the capacity to build up to 180,000 vehicles per year. The goal of the partnership is to advance the EV market in China.

In sum, many other partnerships are forming as companies begin to further explore the future of electrification and deal with opportunities and challenges. While vehicle manufacturers are beginning to offer more electric models to match apparent policy goals and shifting consumer preferences, the supplier responses are likely to dictate the pace. Many suppliers are beginning to invest in research and development regarding electric vehicles, with some adjusting their business models to accommodate R&D commitments. Overall, however, it is apparent that many suppliers see this as a slow transition, and so are focusing on maximizing the efficiency of current ICE vehicles and promoting hybrid vehicle technology.

Digging (Literally) into the Details

In making their announcements, BMW noted that its fifth generation electric engine does not require rare earth metals, one of the minerals suites that have presented distinct constraints for many technologies. As such, the BMW statement serves as a commentary on a core constraint underlying all assumptions for battery energy storage and applications – minerals and materials constituents for effective batteries.

The fundamental challenge with all alternative energy schemes is that energy storage, an attribute inherent in conventional fossil fuels, nuclear material and reservoirs for hydro facilities, must be replaced with something else if those other fuels and technologies are not used. Ergo, battery energy storage for vehicles, to substitute for the foregone benefits of energy storage in conventional vehicle fuels. The same holds for many power grid storage and balancing applications, in particular where intermittent renewable energy sources are included. A chemical battery is an energy storage device; capacity and performance are a function of battery design and chemistry – the combination of minerals and materials that enable charging and release of electricity over multiple cycles and stave off degradation. A wide variety of battery designs exists but additional constraints come in the form of battery weight, safety, and other characteristics that will make a battery design more or less favorable for EV use. Batteries can be significant components of EV cost, including life-time cost with battery replacement. While the main component of commercial EV and grid storage batteries today is lithium, many other minerals and materials are in the mix to solve the gamut of problems and ensure performance.

It is an old rule of thumb that battery storage for mobility is quite a different challenge than for electric power grids which use fixed batteries or other forms of energy storage (water for hydro, again, or compressed air or other solutions, not least advances in the long-time standard, lead acid). Battery designs for mobility must be light and compact, otherwise vehicle designs become unwieldy. EV batteries must meet an assortment of criteria that are essential for consumer acceptance and adoption. "Range anxiety" is a common terminology that captures a first-order priority – EV customers would like these vehicles to travel some distance before batteries must be re-charged. Satisfying performance metrics is essential, especially if electric vehicles are to be successful on a standalone basis, meaning that they are affordable and desirable without public support to close the gap between customer preferences and EV performance.

A current dilemma is that while alluring for many reasons, mainly low weight and high specific energy which have made lithium the preferred material for cathodes, lithium based battery designs are not perfect. Lithium is reactive; cobalt has been used to increase stability but sensitivities around cobalt extraction and supply have triggered a broad search for substitutes. Leading battery scientists believe that batteries need basic re-designs in order to obtain better energy density relative to gasoline (the best lithium batteries still provide 11 or more times the usable energy, even accounting for energy loss during gasoline combustion) and to slow degradation (and prolong battery life). The drive to improve performance puts battery safety at risk. Attempts to store more energy in lithium batteries means risks associated with overcharging, overheating, short circuits and other hazards. Lithium batteries increasingly are treated as hazardous materials for purposes of shipping and cargo safety. Battery production is energy and thus emissions intensive. Assembly of a typical lithium battery today requires 400 kilowatt-hours of energy for one kWh of energy with 75 kilograms of carbon dioxide released. Battery science is moving toward "sustainable" battery chemistry to achieve improvements in life time and safety. Advances are likely to include new chemistries with responsive battery management systems – new sensors with better state of health measurements; better understanding of degradation; new designs that could be commercialized like redox flow batteries.[2]

The changing landscape for battery science has bearing on minerals and raw materials demand and associated resource governance and geopolitical risk factors, how supply chains will evolve, whether effective solutions for recycling can be achieved, how ultimate disposal should be managed, how hazardous materials and other public interest risks are managed throughout. The combination of pressures associated just with chemical batteries and supply chains are such that new frameworks will be required to ensure that public interests are met.

Caveats Emptor

Government jurisdictions at all levels are devising policy/regulatory pushes to encourage, or to force, electrification. Much of the action is at the metropolitan level, in keeping with the urban context we noted earlier. A common approach is to propose bans on ICE vehicles, or at least sales of new ICE vehicles, sometimes with aggressive targets for timing. None of the bans we researched have been enacted into law. Bans have the obvious potential consequence of creating economic distortions and we have found some occasions in which bans are proposed or commitments made subject to economic feasibility.

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