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Markets to Watch:
Electric Vehicles

Executive Summary

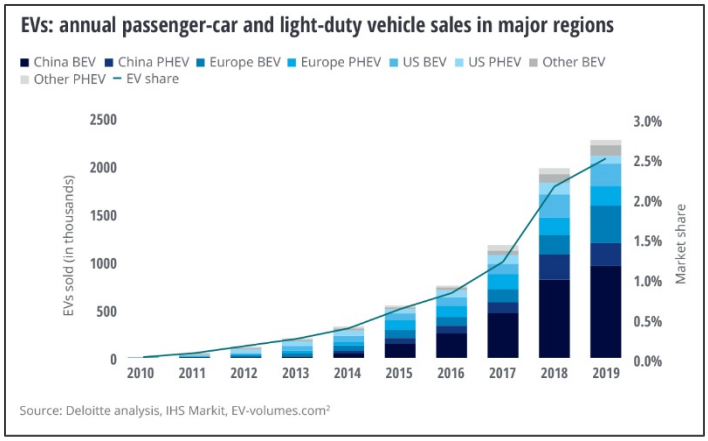
Electrification is everywhere. Almost every day, a new electric vehicle (EV) launch is announced—from the much-hyped Ford F150 Lightning pickup launch in May 2021 to the highly anticipated release of Lucid Motors' sedan (with an expected range of 517 miles per battery charge). Almost 100 new EV models are expected to hit the market by the end of 2024.[i] Volvo, Audi, and GM have pledged to make zero-emissions vehicles *exclusively*, beginning in the next decade.

Spurred on by innovative new models, falling battery prices, policy incentives, and consumer interest in decarbonizing the transportation sector, EV adoption is expected to continue to grow dramatically. Countries like Britain and Norway will ban the sale of internal combustion engines in the next decade, as will the U.S. state of California. Electrification is also expected to take over not only passenger cars, but also delivery vans, trucks, tractors, buses, trains, ferries, container ships, and aircraft. Along with the move to EVs comes additional business opportunities in charging infrastructure, new battery and grid connection technologies, and battery recycling.

The Market

EVs have existed since the birth of the automobile in the late 19th century, but with the historic limitations of battery technology and the relative cost advantage of internal combustion vehicles, EVs all but vanished by the 1930s.[ii] As recently as 2010, EV sales were negligible, with annual vehicles sold of fewer than 5,000 globally.[iii]

In the last decade, EVs have gained tremendous momentum. Globally, 2.1 million passenger EVs were sold in 2019. Nissan, Mercedes-Benz, Volkswagen, Rivian, Hyundai, Volvo, and BMW are just a few of the manufacturers releasing new EV models in 2021. By 2040, Bloomberg New Energy Finance (BNEF) projects that 54 million EVs will be sold annually, representing a 58% market share of passenger vehicle sales. By that point, BNEF expects there to be 500 million EVs on the road, out of a total passenger vehicle fleet of 1.6 billion.[iv] EY's forecast is even more bullish; they predict that EV sales in the U.S., China and Europe will pass all other engine sales by 2033, and that non-EV sales will make up less than 1% of overall sales by 2045.[v]



Source: Deloitte, Electric Vehicles: Setting a course for 2030.
https://www2.deloitte.com/us/en/insights/focus/future-of-mobility/electric-vehicle-trends-2030.html

As a category, EVs include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEV). Along with the growth in the EV market comes demand for batteries and their raw materials. Most EVs use lithium-ion (Li-ion) batteries—the same battery technology used in laptops and cell phones—that are recharged at a consumer's home or workplace, or at public charging stations. In the U.S., there are three categories of charging:

- Level 1: 120-volt AC plug (typical wall outlet), yielding 3 to 5 miles of range per hour
- Level 2: 208-/240-volt AC plug (similar outlet used for dryers and ovens), typically yielding 12 to 25 miles of range per hour

Lead Authors: Eric Denlinger, MBA'22, EDGE Fellow; and Katie Kross, MBA, Managing Director, Center for Energy, Development, and the Global Environment (EDGE), Duke University.

- DC fast charging: 480-volt DC plug, yielding 60 to 80 miles of range in 20 minutes

(Note that these "miles per hour" ranges depend not just on the power rating of the charger, but also the power rating and fuel efficiency of the vehicle, so they are not universal).

Drivers for EV demand include consumer interest in EV performance features (faster acceleration, quieter, less frequent maintenance) and aesthetics, as well as demand for decarbonization in the transportation sector. Transportation accounts for approximately 29% of greenhouse gas (GHG) emissions in the U.S. and 16% of GHG emissions globally, contributing to climate change.[vi] Battery EVs emit no direct tailpipe emissions, so have an inherent advantage over combustion engine vehicles, which emit tailpipe CO_2 (along with other pollutants).

Just how climate-friendly an EV is depends on the source of energy used to charge the vehicle as well as how energy-efficient the vehicle itself is. EVs charged with solar or other renewable energy have the lowest carbon footprint. Even EVs charged with the "dirtiest" power in the U.S., however, have a lower total carbon footprint than gasoline-powered vehicles.[vii] A significant switch to EVs in the U.S. could prevent an estimated 13.5 gigatons of greenhouse gas emissions by 2050 relative to a business-as-usual scenario.[viii]

Trends & Uncertainties

Interest in the EV transition comes from motivated consumers, companies, utilities, and governments. Several trends are shaping—and will continue to influence—the speed of adoption.

Government policies & incentives

One of the more important variables influencing the speed and scale of EV adoption are government policies and incentives, which are expanding in many parts of the world. The U.S., U.K., and 26 of 27 E.U. member countries already offer EV purchase incentives such as tax credits or cash subsidies.[ix] China offers a wide array of incentives for EVs, including purchase subsidies and exempting EVs from urban congestion and parking restrictions.[x] More recently, governments like the UK, France, and Norway have announced plans to prohibit the sale of internal combustion engine vehicles. If more governments join in, these policies could dramatically swing the EV market.

Fleet transformations

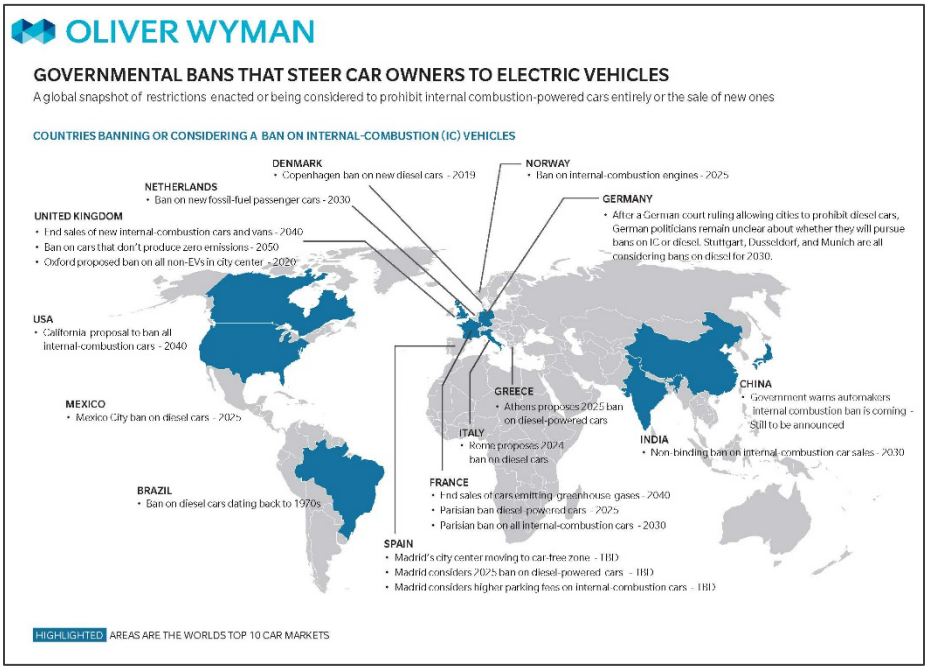
Both corporations and governments are weighing options to shift vehicle fleets to EVs (some of which will be easier than others). Fleet usage could bolster demand for EVs and may also drive investment in additional charging infrastructure. For example, Amazon agreed in September 2019 to purchase 100,000 electric delivery vans from EV manufacturer Rivian.[xi] An association of companies pledging to electrify their fleets—the Corporate Electric Vehicle Alliance—includes AT&T, Hertz, DHL, Uber, Lyft, and other companies. Municipal and state governments, as well as transit authorities and schools (think: buses) could also shape EV demand significantly through fleet transformation.

EV model options

A huge surge in new EV options is on the horizon; fully 500 EV models are expected to be available by 2022[xii] in a wide range of body styles from coupe to SUV to pickup truck. Offering consumers more choice is one key to unlocking broader consumer demand. In their survey of consumers from the U.S., Germany, and China, almost 50% said they are considering purchasing plug-in hybrid EVs or battery EVs as their next car.[xiii]

Preparedness of utilities

Electric utilities are motivated to encourage EV adoption, as it will increase demand for power. However, integration of EVs onto the grid will require additional infrastructure investment. How quickly utilities can adapt may constrain or speed EV adoption rates. In the U.S., widespread adoption of EVs could cause electricity demand to double by 2050, requiring additional investments of $200 billion by utilities.[xiv] Additionally, the time of day that EV drivers plug in is important. In typical commuting patterns, drivers arrive at home in the evening when electricity demand is already at or close to peak demand, so charging at this time exacerbates stress on the grid. In response, many utilities

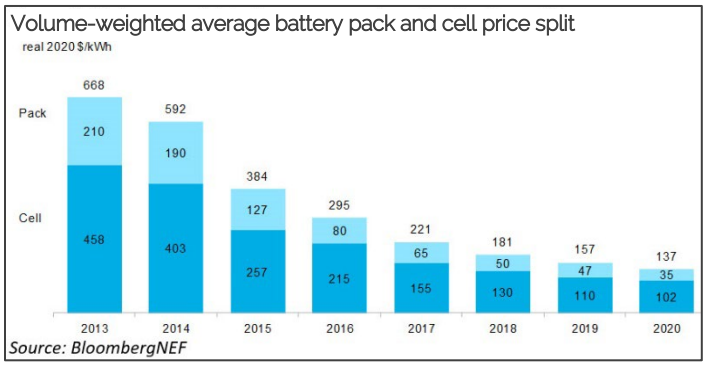


Source: Oliver Wyman, 2018.
https://www.oliverwyman.com/content/dam/oliver-wyman/v2/publications/2018/march/Governmental-Bans-That-Steer-Car-Owners-To-Electric-Vehicles.pdf

offer so-called "time-of-use" electricity plans, which financially incentivize EV drivers to charge during off-peak times when electricity demand is lower.

Availability of charging
Many potential EV consumers have limits on their ability to set up home charging stations (for instance, renters in multifamily units or homeowners who park on the street or in a shared garage). For EV adoption to become widespread, more investment will need to be made in charging infrastructure. Research by Atlas Public Policy estimates that supporting EVs in the U.S. will require $39 billion of investment in public charging infrastructure, as well as another $48 billion in multi-unit home charging, single-family home charging, and depot charging infrastructure.[xv]

Falling battery costs
EVs are expected to reach price parity with internal combustion engine vehicles by 2025, largely driven by the reduction in the price of batteries, which have fallen 87% in real terms from 2010 ($1,100 per kWh) to 2019 ($156 per kWh), while at the same time becoming more energy efficient.[xvi]



Falling battery costs. Source: Bloomberg New Energy Finance, 2020.
https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh

Availability of battery raw materials
Demand for Li-ion batteries for use in EV and energy storage is projected to soar from 526 gigawatt hours (gWh) in 2020 to 9,300 gWh by 2030.[xvii] Globally, manufacturers have announced $600 billion in EV and energy storage Li-ion battery capacity investments for 2022.[xviii] However, such an increase in production has caused concern about supply shortages for key minerals used in battery production such as lithium, cobalt, and nickel. More than 70% of the world's supply of cobalt is sourced from the Democratic Republic of the Congo, whose mines have been connected with the use of child labor.[xix] Additionally, 40% of cobalt mining capacity in the DRC is controlled by Chinese companies, which may make the mineral subject to geopolitical tensions.[xx] The battery market could hinge on whether new mineral resources become available (for instance, through deep sea mining) or whether new battery technologies become available. For instance, Tesla has already announced plans to shift to cobalt-free batteries.

SPACs
There has been a recent boom in EV manufacturers and charging infrastructure startups going public via special purpose acquisition companies (SPACs)—some with mixed success to date. Lordstown Motors and Nikola Motor are two notably visible bad actors with recent market losses.[xxi] It remains to be seen whether investors' enthusiasm for EV SPACs will be affected by these high-profile examples or continue unabated.

Autonomous (self-driving) vehicles
Autonomous vehicles (AVs) that are being developed and tested by companies like Tesla, Cruise, and Waymo may or may not contribute to the EV trend, depending on how their fleets are designed. Limited availability of fast chargers may be one limiting factor (AVs deployed as robo-taxis will need to recharge often); however, most AV companies are currently testing EV models and regulation could require AVs to be electric in some markets.

Transformation of existing industries
Most of the major auto manufacturers are adapting manufacturing lines to accommodate at least some portion of their sales to EVs in the future. Automotive suppliers who supply parts specific to combustion vehicles may need to diversify. The share of an EV's value added by suppliers often totals 35% to 40%, compared with 50% to 55% for an internal combustion engine vehicle.[xxii] There may also be important impacts on the automotive repair market; EVs generally require less maintenance and last longer (in terms of vehicle mileage) than combustion engine equivalents, and require technicians trained in high-voltage vehicle maintenance and repair.

Business Opportunities

The growth of the EV market presents new opportunities for investors not only in car manufacturing, but also across the entire EV and mobility supply chain. Below are the biggest EV market opportunities to watch.

Electric cars
Though EVs are still a small fraction of the overall $20 billion new car market, growth prospects are rosy. There will be 500 EV models available on the market in 2022.[xxiii] EV models are have been released from all of the traditional players—Ford, Porsche, BMW—as well as EV-only companies like Tesla, Lucid Motors, and NIO. Big tech companies have reportedly shown interest in EVs. Apple, for instance, is rumored to be eyeing a 2024 date to begin production of an EV.[xxiv]

Electric buses, vans, and trucks
In addition to passenger cars, many investors see opportunities across the full spectrum of medium- and heavy-duty trucks, buses, and delivery vans. In 2021, Rivian

will begin delivering the first of 100,000 delivery vans to Amazon. Proterra and Canoo in the U.S. and Arrival in the UK are selling electric buses and delivery vans. Tesla, Daimler Trucks, and Volvo Trucks are taking orders for electric semis. Innovation may be further spurred in the U.S. by the Dept. of Energy, which announced the "SuperTruck 3" program to invest $100 million in R&D and road testing of electric trucks and equipment.[xxv]

Charging infrastructure, software & services
In order to accommodate the projected growth in EV adoption, a huge investment needs to be made in charging infrastructure. ChargePoint, EVgo, and Electrify America, a Volkswagen subsidiary, are building public charging networks, while Tesla and Rivian are building their own charging networks for their vehicle owners. Ford recently acquired Electriphi, a startup providing software to charge and monitor EV fleets. Other firms, like WiTricity are working on wireless charging infrastructure for EVs. Future infrastructure could embed wireless charging directly in roads, so vehicles could automatically charge as they are driven (called "dynamic charging").

Battery manufacturing & recycling
Some automakers are expanding into the production of battery packs. For example, GM is constructing a new battery plant in Ohio, in a joint venture with LG Chem, to manufacture its "Ultium" battery technology.[xxvi] Other businesses are investing in second-life battery applications (eg, deploying used EV batteries in grid-scale energy storage applications) and battery recycling services.

New battery technologies
Solid-state batteries (so-called because the electrolyte that conducts the electric current is a solid rather than a liquid) are touted as being able to charge faster, provide more energy density, and last longer than current Li-ion batteries. QuantumScape, one company that is working to commercialize solid-state batteries, unveiled test data that showed its battery could charge as much as 80% in just 15 minutes.[xxvii] Enevate, a California-based company, raised $81 million in Series E funding in early 2021 to commercialize an ultrafast charging battery.[xxviii] BMW and Ford have likewise invested in the solid-state battery startup Solid Power.[xxix]

Vehicle-to-home and vehicle-to-grid (V2G) integration
Just as EVs draw energy from the utility grid to charge their batteries, they are capable of supplying power from their batteries to other devices (like tools or electronics) or back to a home or other building, or to the grid itself. The Ford F150 Lightning touts its ability to be used as a backup power system as one of its features, claiming that, with an integration package installed, the truck's battery can provide full home power for up to three days. Innovation will likely drive more applications in bi-directional power and V2G integration (including both hardware and software applications) associated with EVs in the future.

Mobility as a service
Plenty of investors are betting right now on AVs as well as "mobility as a service" business models that would eliminate the need for car ownership in big cities. How the AV future plays out—and the extent to which it is fully electric or not—will hinge greatly on regulatory decisions made in the next decade as well as consumer demand.

Takeaways for MBAs

1. EV sales are growing rapidly, driven by in part by consumer interest, EV model availability, falling battery costs, fleet decarbonization goals, and government incentives.
2. Issues to keep an eye on include: large increases in electricity demand, Li-ion battery supply concerns, and the availability of public charging infrastructure.
3. A number of new technologies, such as solid-state batteries, wireless charging, and vehicle-to-grid, promise further innovation in the rapidly growing EV industry.

Further Reading

Electric Vehicle Outlook 2020, Executive Summary, Bloomberg New Energy Finance, 2020.

The irresistible momentum behind clean, electric, connected mobility: Four key trends, McKinsey & Co., 2021.

Electric vehicles: Setting a course for 2030, Deloitte, 2020.

Global EV Outlook 2021, International Energy Association, 2021.

[i] https://www.consumerreports.org/hybrids-evs/hot-new-electric-cars-are-coming-soon/
[ii] https://www.energy.gov/articles/history-electric-car
[iii] https://evadoption.com/ev-statistics-of-the-week-historical-us-ev-sales-growth-market-share/
[iv] https://about.bnef.com/electric-vehicle-outlook/
[v] https://www.ey.com/en_gl/news/2021/06/electric-vehicles-to-dominate-sales-five-years-sooner-than-expected-ey-analysis
[vi] https://www.climatewatchdata.org/key-visualizations
[vii] https://blog.ucsusa.org/dave-reichmuth/are-electric-vehicles-really-better-for-the-climate-yes-heres-why/
[viii] https://www.wsj.com/graphics/are-electric-cars-really-better-for-the-environment/
[ix] https://www.acea.be/uploads/publications/Electric_vehicles-Tax_benefits_purchase_incentives_European_Union_2020.pdf
[x] https://www.sustainalytics.com/esg-blog/how-chinas-electric-vehicle-policies-have-shaped-the-ev-market/#_edn4
[xi] https://www.cnbc.com/2020/06/23/amazon-launches-2-billion-fund-to-invest-in-climate-technologies.html
[xii] https://about.bnef.com/electric-vehicle-outlook/
[xiii] https://www.bain.com/insights/electric-and-autonomous-vehicles-the-future-is-now/
[xiv] https://www.reuters.com/article/us-usa-weather-grids-autos-insight/ev-rollout-will-require-huge-investments-in-strained-u-s-power-grids-idUSKBN2AX18Y
[xv] https://atlaspolicy.com/rand/u-s-passenger-vehicle-electrification-infrastructure-assessment/
[xvi] https://about.bnef.com/blog/battery-pack-prices-fall-as-market-ramps-up-with-market-average-at-156-kwh-in-2019/
[xvii] https://www.statista.com/chart/23808/lithium-ion-battery-demand/
[xviii] https://www.iea.org/data-and-statistics/charts/commissioned-ev-and-energy-storage-lithium-ion-battery-cell-production-capacity-by-region-and-associated-annual-investment-2010-2022
[xix] https://www.forbes.com/sites/michaelposner/2020/10/07/how-tesla-should-combat-child-labor-in-the-democratic-republic-of-the-congo/?sh=452f105e5cd0
[xx] https://www.mining.com/what-chinas-increasing-control-over-cobalt-resources-in-the-drc-means-for-the-west-report/
[xxi] https://climatetechvc.substack.com/p/-ev-spacs-running-out-of-charge-60
[xxii] https://www.pwc.com/us/en/industries/industrial-products/library/electric-vehicles-supply-chain.html
[xxiii] https://about.bnef.com/electric-vehicle-outlook/
[xxiv] https://www.caranddriver.com/news/a35036439/apple-car-2024/
[xxv] https://www.canarymedia.com/articles/doe-commits-100m-in-push-to-put-electric-trucks-on-the-road/
[xxvi] https://media.gm.com/media/us/en/gm/ev.detail.html/content/Pages/news/us/en/2020/jul/0729-ultium-cells.html
[xxvii] https://www.wsj.com/articles/the-leaders-in-the-race-to-build-a-better-ev-battery-11610706600
[xxviii] https://www.businesswire.com/news/home/20210210005278/en/Fidelity-Leads-81M-Investment-in-Enevate-to-Accelerate-Commercialization-of-Fast-Charging-Electric-Vehicle-Battery-Technology
[xxix] https://www.canarymedia.com/articles/solid-power-bmw-ford-solid-state/