ClearBridge Investments

Why EV Adoption is Poised to Accelerate

Key Takeaways

- Improvements in range, charging availability and affordability are driving increased sales of electric passenger vehicles and causing a shift away from hybrid models.
- Lower battery costs, greater commercial adoption and pro-environmental transportation regulations are also sparking a shift from internal combustion to electric powertrains.
- The convergence of several new technologies and business models, highlighted by autonomous driving, could significantly accelerate EV adoption over the next decade.

2019 – The Year of Model 3

In a year where overall total passenger automobile sales declined, plug-in electric vehicles (EVs) continued to grow and gain market share. Globally, EV (battery electric and plug-in hybrids) sales grew by around 9% to 2.2 million (Exhibit 1). EV market mix continued to shift toward pure battery electric cars which grew 17% to 1.6 million and accounted for 74% of all EVs.

In U.S. and European markets, 2019 was clearly the year of Tesla's Model 3, which has shown that an attractively designed and well-priced electric car can capture substantial market share from its internal combustion engine (ICE) competitors. In the U.S., Model 3 sales were higher than sales of its three category peers combined (Exhibit 2). The Model 3 retails at a similar price (without any subsidies) as these competing models, however it offers owners significant fuel savings over time.

The European EV market grew by 46% to 564,000 in 2019, driven by strong growth of battery electric vehicles (BEVs). In countries such as Sweden and Holland, more than every tenth car sold had an electric plug. In Norway, the global leader in electrification, 40% of new cars sold were battery electric and an additional 16% were plug-in hybrids.

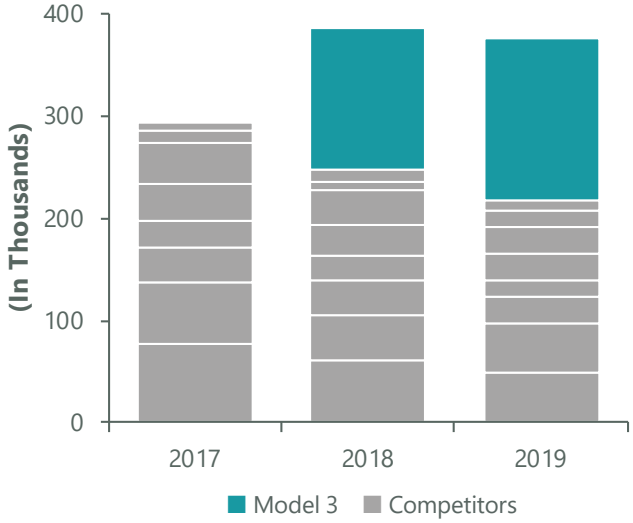
Exhibit 1: Passenger Global EV Car Sales Trends (Thousands)

Region	2018	2019	Change
China	1,102	1,118	1%
Europe	386	564	46%
USA	361	329	-9%
Other	169	199	17%
Total	2,018	2,210	9%

EV Type	2018	2019	Change
Battery-Electric (BEV)	1,393	1,635	17%
Plug-in Hybrids (PHEV)	626	575	-8%
Total	2,018	2,210	9%

Source: Insideevs.com, ev-sales.blogspot.com, ClearBridge Investments.

Exhibit 2: Tesla Now Leads Premium Mid-Size Sedans Category



Source: Company reports, InsideEV, ClearBridge Investments. Competitor models include Mercedes C, BMW 3, Audi A4, Lexus IS, Acura TLX, Infiniti Q50, Volvo S60, and Alfa Romeo Giulia.

In the U.S., like in Europe, the EV market continued to shift toward pure BEVs and away from plug-in hybrids. Tesla models alone garnered an impressive 60% of the EV market but several other original equipment manufacturers (OEMs) have also introduced new long-range electric models including the Audi e-Tron, Jaguar I-Pace and Hyundai Kona. Sales of plug-in hybrids — cars that have both a combustion engine and a small battery — declined significantly, led by the discontinuation of the Chevy Volt. As a result, the average size of batteries installed in cars continued to grow.

A longer-lasting EV would reduce depreciation costs dramatically. For a fleet operator, instead of buying two or more ICE cars it could use just one EV for the same mileage.

In China, sales of EVs increased only modestly in 2019 as a result of substantial subsidy changes during the year. However, because the whole market declined, EV share increased again and reached over 5% of the market. Chinese authorities signaled that no further subsidy cuts are planned for 2020. Longer term, Beijing continues to push automakers to build more electrified products through quotas and a "carbon credit program" and expects EVs to account for 25% of new light-vehicle sales in 2025.

Adding to this momentum, the electric powertrain is increasingly being implemented outside the passenger car market. Electric city buses have seen good growth in China for the last few years, with an average of 100,000 e-bus sales per year. However, as the cost of batteries declines, e-bus adoption is growing in other markets as well. In Europe, sales of electric and hybrid city buses more than doubled to 3,644 units in 2019. Battery electric bus registrations alone now account for 12% of all city buses registered in Europe.

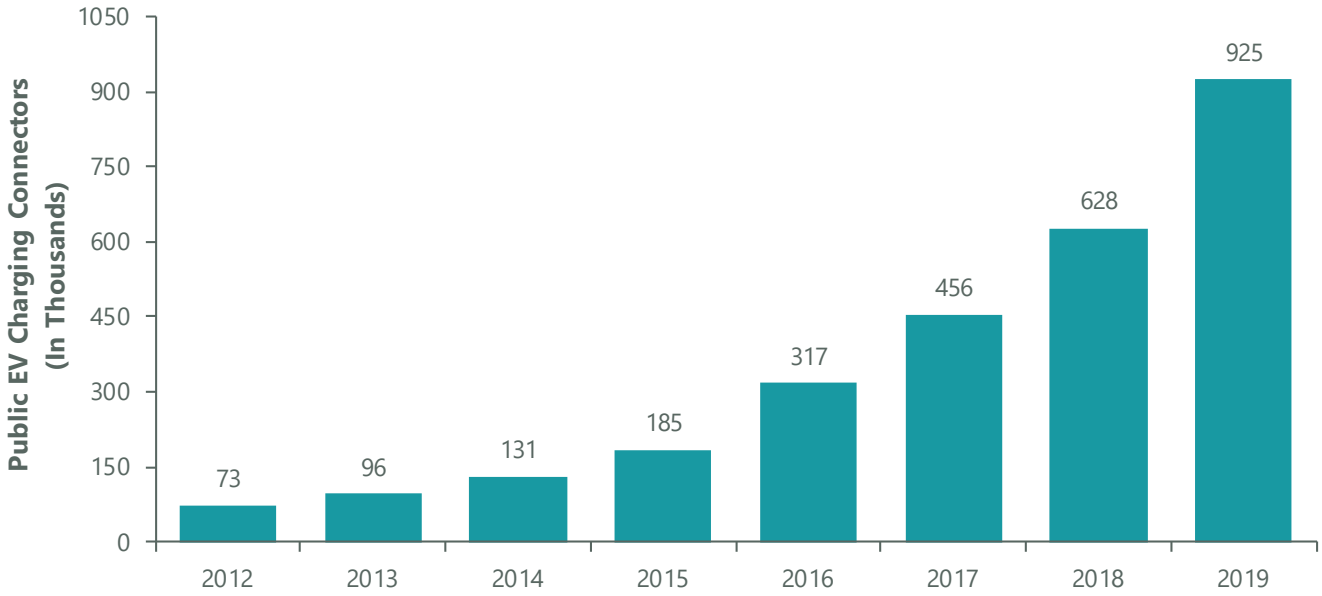
Lithium-ion (li-on) battery powered electric motorcycle and scooter sales have been growing strongly in Asia for some time, and we now see strong growth in Europe as well. In 2019, the European electric motorcycle and scooter market grew 50% to 80,000 units or about 5% of the market. This followed 100% growth in 2018. The market is dominated by the Chinese manufacturer NIU and Italy's Askoll.

Range and Charging Infrastructure Keep Improving

Over the last few years, we have seen a steady improvement in the availability of EV charging stations as well as the driving range on a single charge. EV charging infrastructure continues to grow rapidly. According to Bloomberg New Energy Finance (BNEF), there were 925,000 public EV charging connectors installed globally at the end of 2019, up five times from 185,000 in 2015 (Exhibit 3).

The average range that an electric car can drive on a single charge continues to improve as well. The average range of BEVs rose from just 70 miles in 2011 to 182 miles for models launched in 2019.

Exhibit 3: Growth in Charging Infrastructure



Source: Bloomberg New Energy Finance.

The range of upcoming models is higher still at 235 miles for BEVs launching in 2020, with the upcoming Tesla Model Y having a range of 315 miles.

Technology is also improving the charging speed. While most charging is currently performed at home or destinations, charging speed on the road is also crucial for EV adoption. Tesla recently launched a new generation of superchargers. Its new 1-megawatt (MW) power cabinet supports peak rates of up to 250 kilowatt (kW) per car. At this rate, a Model 3 Long Range operating at peak efficiency can recover up to 75 miles of charge in five minutes and charge at rates of up to 1,000 miles per hour. IONITY, a joint venture between BMW, Daimler, Ford and Volkswagen, is currently building a high power (350 kW) charging network for EVs along major highways in Europe. IONITY claims that a vehicle capable of the full 350 kW charging power can be charged in approximately 10 to 15 minutes, significantly faster than charge times at more common 50 kW charging stations.

Drivers of Growing EV Adoption

1. Battery Costs Continue to Fall

Battery costs, which are the key enabler of EV market growth, continue to decline rapidly. Automotive battery costs declined by 16% in 2019 to below $147/kilowatts per hour (kWh), according to BNEF. Since 2012, the year that Tesla launched its Model S, average li-on battery costs have fallen by a cumulative 78%, allowing automakers to launch increasingly affordable models.

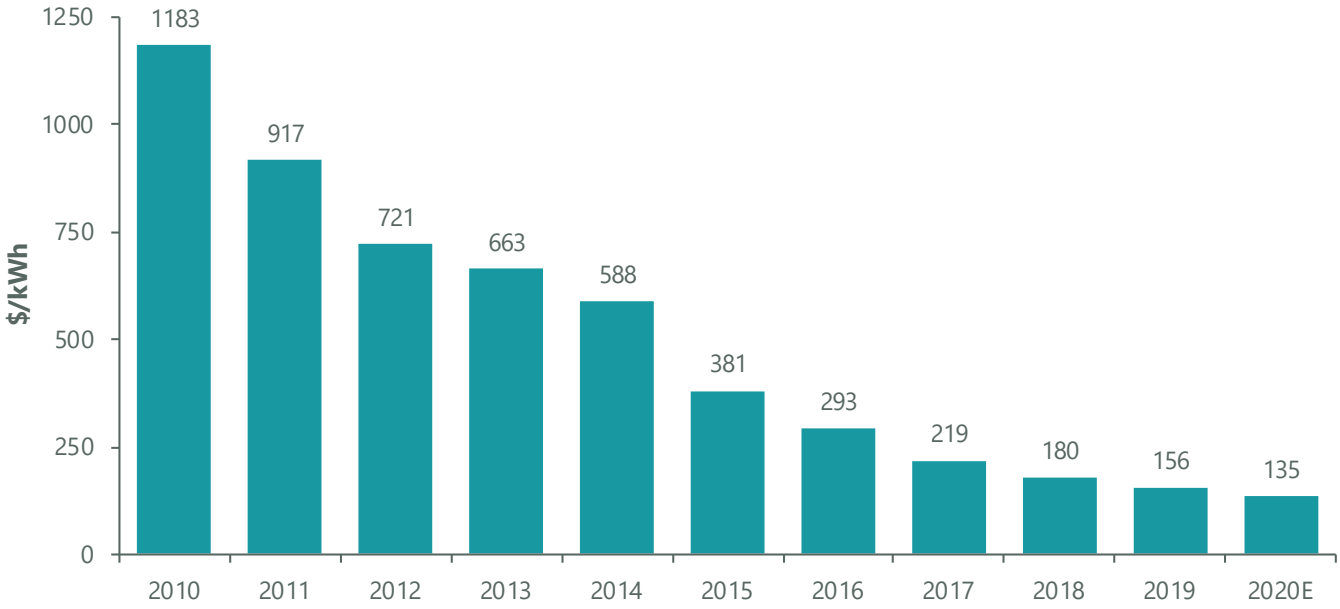
Using the observed 18% learning curve, which measures the historical relationship between growing volume demand for batteries and declining battery prices, BNEF estimates prices will fall below the $100/kWh level around 2023 (Exhibit 4). This is the point where mass market EVs are considered to reach price parity with ICEs across most segments of the car industry (some high-end EVs have already reached parity). Manufacturing scale and consolidation of battery makers, better chemistry and new modular battery pack designs are just a few key drivers of the ongoing improvements in rechargeable li-on batteries.

2. Pro-EV Regulation

Political and regulatory support for EVs is broadening in many parts of the world. As EVs become more affordable and more visible on the city streets, it becomes increasingly difficult for politicians at various levels of government to ignore supporting EVs. There is also increasing awareness of health risks posed by car emissions, especially in cities where most emissions occur.

On a regional level, the EU has agreed on new targets to lower new car CO2 emissions by 15% from 2021 levels by 2025 and by 37.5% from such levels by 2030. Achieving the targets will require

Exhibit 4: Lithium-ion Battery Prices Keep Falling



Source: Bloomberg New Energy Finance.

carmakers to upgrade their strategy to comply with increasingly more stringent regulations. It will become increasingly more expensive to meet these goals simply through improvements in better engine technology and will require a meaningful shift to EVs.

Even meeting the 2020 targets, which come fully into effect in 2021, will require a substantial reduction in fleet average emissions across almost all OEMs in Europe to avoid significant fines. Therefore, we expect OEMs to encourage EV adoption by introducing more models and pricing those models favorably, as selling more of these EVs at prices which would appear to be a loss may end up being profit positive due to the ability to reduce the fines from failure to comply with the emissions regulations. Most EU countries have also introduced incentives for EVs. Twelve offer bonus payments for EV buyers and most offer a tax reduction or exemption for buyers and owners of EVs.

On a local level, many cities in Europe have recently implemented restrictive vehicle entry regulations. These include low emission zones where most polluting vehicles cannot enter or are charged a higher fee than zero-emission vehicles. Over the next decade, 24 European cities with a total population of 62 million people will ban diesel vehicles, and 13 of those cities will ban all ICE cars by 2030.

In the U.S., the Los Angeles Green New Deal is targeting 100% electric buses by 2030 for the LA Metro and LA DOT fleets, installing 28,000 EV chargers citywide and seeking to increase the percentage of zero-emission vehicles to 25% by 2025.

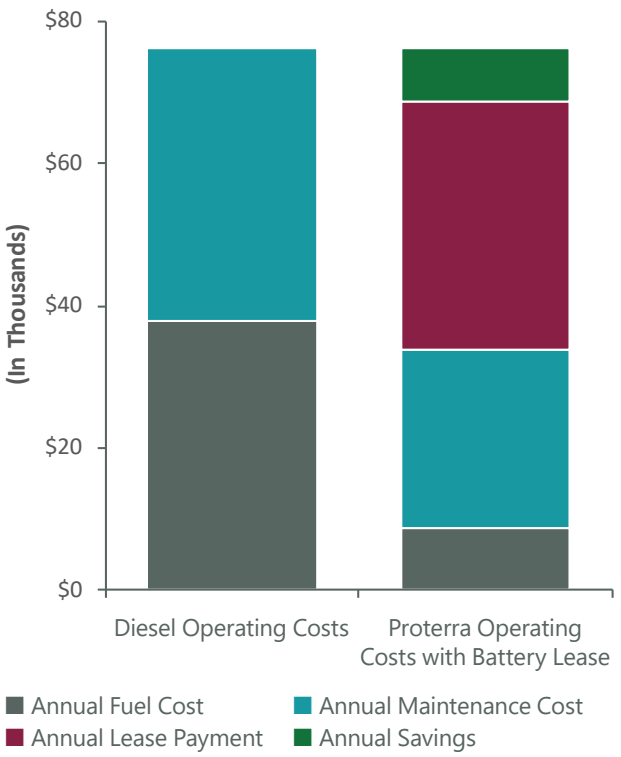
In New York City, the new capital plan of the MTA, the largest operator of city buses in the U.S., envisages a transition to a fleet composed fully of zero-emission electric buses. Between now and 2024, the MTA plans to invest $1.1 billion to modify depots for electric bus operations and purchase 500 electric buses. The program enables the MTA to acquire only electric buses beginning in 2029.

All of these regulations will increasingly impact the residual and resale values of ICE vehicles and push manufacturers to dedicate a larger percentage of capex and R&D toward further electrification.

3. Strong Economics for Fleets, Led by Amazon

We expect commercial fleets to increasingly adopt EVs due to favorable economics relative to the ICE platform. Fleet users see the majority of their total operating costs weighted toward variable operating costs and depreciation of those fleets relative to the initial purchase price of the vehicle. Given that EVs last longer and have lower fuel and maintenance costs, they are becoming an increasingly attractive

Exhibit 5: Financing Buses with a Battery Lease



Source: Proterra.

choice for fleet owners. Even with current technology, the EV payback for high-utilization fleets (taxis, delivery companies) is already attractive.

Morgan Stanley estimates that an EV operated in a mega-fleet could have a payback of just three years. There is also increasing evidence that a modern electric power train with an efficient cooling system can last much longer than an ICE powertrain. A longer-lasting EV would reduce depreciation costs dramatically. For a fleet operator, instead of buying two or more ICE cars it could use just one EV for the same mileage.

In 2019, we saw the first large-scale order for electric commercial trucks. Amazon.com reported an order with privately owned company Rivian for 100,000 electric delivery vans. While this investment is part of a broader climate pledge by Amazon, the expectation of good economics of operating an EV fleet must also have played a role. United Parcel Service recently ordered 10,000 electric vans from privately held Arrival and will collaborate with the company to develop a wide range of electric vehicles with advanced driver-assistance systems.

4. New Business Models Supporting EV Growth

Historically, major disruptions have developed as a result of the convergence of several technologies and/or due to the emergence of new business models that exploit those technologies. While declining costs of batteries will continue to drive EV adoption, various new business models and development of new technologies could significantly accelerate that adoption over the next decade. Examples of new business models include:

a. **Battery Leasing:** The upfront cost of an electric bus remains a barrier for many transit agencies looking to implement zero-emission vehicles into their fleet. Battery leasing is a new business model that enables a faster transition to electric buses for commercial fleets. Proterra, a privately-owned U.S. company, already has more than a dozen customers participating in its battery lease program. By decoupling the batteries from the sale of its buses, Proterra enables transit customers to purchase the electric bus at a capital expense similar to that for a diesel or compressed natural gas (CNG) bus. Customers can use the operating funds previously earmarked for fuel to pay for the battery lease (Exhibit 5).

b. **Vehicle-to-Grid:** New applications are evolving where EV batteries can be used as back-up power for the grid. Recently, U.S.-based Dominion Energy partnered with local Virginia school districts to begin replacing diesel buses with 100% electric school buses. The buses can be used as batteries for the grid or for electricity use off the grid. Dominion Energy shares, "When not in use, they can be tapped as an energy resource through vehicle-to-grid technology. If energy needs are high or if renewable resources are intermittent, the batteries can provide stability to the grid. During a power outage or emergency, the batteries could serve as mobile power stations." 1,050 electric buses could provide enough energy to power 10,000+ homes.

   This technology extends the benefits of electric buses beyond clean transportation and greatly reduced pollution. A fleet of school buses could be a valid source of distributed power because their usage patterns are predictable. They are idle at precisely the times when energy demand is at its peak — midday and during the hottest summer months. By storing or drawing power from a fleet of parked school buses, utilities can avoid wasting surplus energy from renewables or cranking up a natural gas power plant.

c. **Free EV Charging:** Increasingly free EV charging is offered as a marketing tool by various shopping malls, hotels and restaurants to attract traffic and customers. Municipalities have also provided free charges to residents to support local commerce. Tesla currently offers its clients an extensive network of so-called destination chargers. These chargers are typically owned by hotel or resort owners and charging is free to customers.

   A recent study by Volta, a private U.S. company providing free charging solutions to real estate owners, indicated most respondents would be willing to try out a new shopping center that provides free charging and that they would visit more often. The company does not charge per electrons but instead partners with brands that want to advertise on the billboards that are displayed on the charging poles. The company claims to have delivered nearly 61 million free electric miles to customers using their chargers.

Opportunities in an Accelerating EV Market

The convergence of three technology trends — artificial intelligence, electric vehicles and transportation-as-a-service (TAAS) — can help enable the next generation of consumer and commercial transportation: autonomous driving. As a result, we see a number of companies well exposed to these trends.

U.S. semiconductor developer Nvidia is a market leader in enabling artificial intelligence technologies and has also rolled out a suite of products to address multiple steps in the autonomous driving value chain, from training computer systems using simulated driving conditions to processors inside of vehicles that can apply those models to real world situations. We also favor U.S. technology firm Cree, a leading supplier of silicon carbide (SiC) wafers and devices, as we believe that EVs will eventually adopt SiC for battery power management solutions as it is far more efficient than traditional silicon. We also see this as a key enabling technology for fast charging, as SiC fast chargers can add 75 miles of range in just five minutes of charging.

We are monitoring these developments closely and evaluating companies that can participate in these trends. In addition to public companies that support li-on battery development including U.S. lithium producer Albemarle, Chile's Sociedad Quimica y Minera (SQM) and Belgian cathode maker Umicore, as well as Japanese electric motor manufacturer Nidec, we are also following several private companies such as Proterra, Zero Motorcycles, ChargePoint and Zoox that could play key roles in EV innovation.

Autonomous Driving a Natural Fit for EVs

Autonomous vehicle (AV) technology: While the enthusiasm around the timing and regulatory approval of autonomous vehicles has subsided lately, the technology is evolving rapidly. Dozens of companies continue testing AV fleets and investments in the space continue to grow. Waymo has already concluded over 20 million self-driving miles on public roads. Tesla, through an over-the-air update, pushed the "Navigate-on-Autopilot" feature that allows cars to be driven autonomously — with driver supervision — on most highways.

It is difficult to predict when AV technology will be available and approved by regulators. However, many technologies behind AV are improving at exponential rates. Computing, deep learning networks and sensors are all improving meaningfully. The amount of gathered data is also rising.

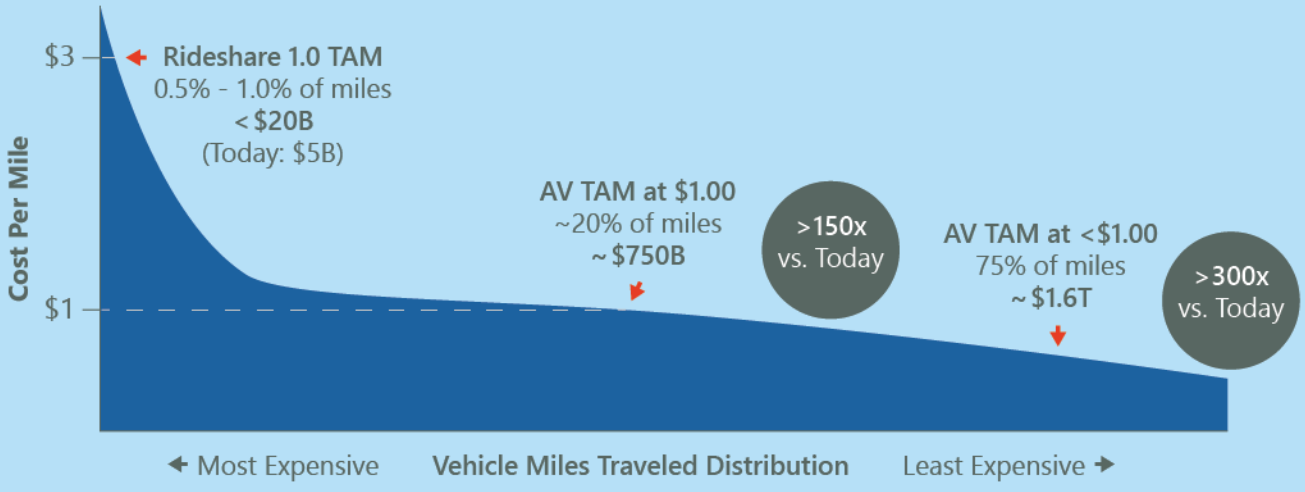
So, while AVs are a theoretical exercise at this stage, we believe their eventual introduction would have significant implications for the adoption of EVs. Due to economics of the EV powertrain, it is likely that most AVs will be fully electric. AVs owned by fleets would have much higher utilization rates than privately-owned cars. This, combined with lower depreciation, fueling and servicing costs, means that AVs operated by fleets would be able to offer costs per miles several times lower than driving a privately-owned ICE car.

Several companies have presented a compelling case for the economics of robo-taxis operated by fleets. Cruise (owned by GM), for example, recently launched a new self-driving platform called Cruise Origin. It is an electric AV with no steering wheel, no rearview mirrors or pedals designed to last one million miles or six times more than an average car. Cruise estimated that an average San Francisco household driving themselves or using ridesharing will save up to $5,000 per year on average.

On its recent Autonomous Day, Tesla unveiled plans to bring AV cars to the market. According to Tesla, the average cost of running an autonomous electric robo-taxi will be only $0.18 per mile compared to the average U.S. car ownership cost of $0.62 per mile. Waymo recently opted for an electric car to expand its robo-taxi fleet, partnering with Jaguar Land Rover to develop self-driving EVs for its driverless transportation service. Waymo will purchase 20,000 electric Jaguar I PACEs and equip them with its self-driving technology.

As costs decline, more of the transportation market will naturally shift over to AV. GM estimates that about 75% of all miles driven would be addressable by self-driving technologies once costs fall below $1.00/mile (Exhibit 6).

Exhibit 6: As Self-Driving Costs Decline, Market Should Take Off



Source: General Motors. TAM: Total addressable market.

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